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Rediscovery of the Unusual Genus *Ormiscocerus* (Neuroptera: Berothidae: Cyrenoberothinae)

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***Ormiscocerus nitidipennis*, the type species of the genus *Ormiscocerus* Blanchard, 1851, is redescribed after 155 years of uncertainty as to exactly what it was that Blanchard had before him. Our description is based on new male specimens. Based on this new material, we are now able to place the genus in a phylogenetic context, referring it to the neuropteran clade that includes the most primitive known berothids. A neotype for *Ormiscocerus nitidipennis* Blanchard is designated.**

In 1851, Charles Émile Blanchard described a new species of neuropteran, in what was then the broadly defined Hemerobiidae, from Claudio Gay's collection of Chilean insects. The description was accompanied by a detailed habitus drawing, which is reproduced here (Fig. 1). Even allowing for early artistic inaccuracies, this was a most unusual species with small size, prognathous mouthparts, antennae inserted anterior to the eyes, elongate pronotum, expanded forecoxae, and rounded tips to the wings. Brauer (1866) suggested that this species might be more closely related to *Raphidia*, probably because of the prognathous mouthparts and elongate pronotum. The description had been based on an unspecified number of specimens. Gay's Collection is now housed in the Muséum National de Histoire Naturelle, Paris (NMHN), but a search for the type specimen(s) of this species by John Oswald in 1989 proved unsuccessful (Oswald 1993). Because of this, in his 1993 revision of the family Hemerobiidae, Oswald chose to retain *Ormiscocerus nitidipennis* Blanchard as an *incertae sedis* within the Neuropterida.

In 1999, Monserrat and Deretsky described a new species of Hemerobiidae from Chile, *Berothimerobius reticulatus*, with several unusual features. They compared it to *Ormiscocerus nitidipennis*, and surmised that *Ormiscocerus* might be a berothid. They, too, mentioned that the type(s) of *Ormiscocerus nitidipennis* had been lost. Also, in two trips to study the Neuroptera collection of the Paris Museum, one each in 1980 and 1999, NDP could not find the type(s) of *Ormiscocerus nitidipennis* and subsequent e-mails to the curator at the Paris Museum have gone unanswered.

In recent Malaise trap samples sent by Michael E. Irwin to SLW from Chile, there is a male specimen of what appears to be *Ormiscocerus nitidipennis*. In going through Phil Adams' correspondence, NDP came across a rather detailed wing drawing sent to Adams of a second Chilean male specimen that appears quite similar to the one sent to SLW. The second specimen was located in the collection of Ellis MacLeod (now in the possession of John D. Oswald at Texas A&M. University).

Based on the confusion surrounding the identity of this species, the apparent loss of the original type(s), and the recent discovery of two new specimens, we take this opportunity to designate

a neotype for *Ormiscocerus nitidipennis*, redescribe the species, and place it in a phylogenetic context.

Materials and Methods

The specimen that we shall designate below as the neotype is preserved in a vial of 95% ETOH. The second specimen has been disarticulated and is preserved in four microvials of glycerin as follows: (1) head and left wings; (2) right wings; (3) abdomen; and (4) gut contents. The abdomen of the neotype has been stained with Chlorazol Black E for 20 minutes.

All observations were made with the aid of a 50X Olympus dissecting microscope.

Genus *Ormiscocerus* Blanchard

Type species: *Ormiscocerus nitidipennis* Blanchard in Gay, 1851:129, Plate X, fig. 11.

Diagnosis.— Head prognathous. Antennal flagellomeres reduced to 18. Pronotum longer than wide. Forewing with one radial sector; Sc and R broadly separated, with 10 subcostal crossveins; apex of veins enlarged and darkened; apical margin of wing rounded. Recurrent humeral crossvein reduced to a basally directed branched crossvein. Male genitalia reduced to two sclerites: a thin, arched gonarcus; and a pair of thin apically elbowed parameres that almost fuse medially, with only a thin membrane separating the two parameres apically.

Included species.— *O. nitidipennis* Blanchard, 1851; Chile.

Ormiscocerus nitidipennis Blanchard, 1851

Type.— Neotype: male labeled *Ormiscocerus nitidipennis* Blanchard (Figs. 2–6): "Chile. Region IV, Elqui Prov.,/ Quebrada El Arrayán, 10 km S[outh of]/ La Villa; malaise in dry wash;/ 5-X-2003, M.E. Irwin, 400 m,/ 30°04.26′S, 71°00.04′W." Deposited in California Academy of Sciences, San Francisco.

Head.— Prognathous, black. Mouthparts very short. Mandibles black, extended laterad and just beyond tip of pale labrum; tip curved medially. Maxillary palpi four-segmented, last segment tapered to point. Clypeus with two lateral pair of small setae along ventral margin. Labium short, extended only to anterior margin of compound eye; labial palpi dark, three-segmented, apical segment tapered to point. Frons dark brown with small white spot at medial margin of eyes. Compound eyes small. Occiput dark, covered with small coarse chalazate setae; coronal suture not visible. Ocelli absent. Length of head behind eyes about as long as eye length, not elevated. Antennal bases between eyes; scape and pedicel dark, about twice as long as wide, covered with sparse, stout spines. Flagellum with 18 flagellomeres, basal flagellomeres dark basally and pale apically.

Thorax.— Pronotum slightly longer than wide; dark brown with thin white medial stripe interrupted twice at mid-length; pronotum with numerous chalazate setal bases. Premesoscutum narrow, strap-like, dark brown with white marks at mid-line and lateral margins; mesoscutum dark brown with four white spots; mesoscutellum dark brown, unmarked. Metanotum dark brown, unmarked. Pleural and sternal regions mottled pale brown with dark brown margins along sutures.

Legs.— Pale yellow. Forecoxae large, cylindrical, longer than either femur or tibia, with

Figures 1–6. (1) *Ormiscocerus nitidipennis* Blanchard in Gay. Original habitus drawing reproduced from Blanchard (1851). (2) *Ormiscocerus nitidipennis* Blanchard in Gay. Habitus photograph of neotype by S. Winterton. (3) *Ormiscocerus nitidipennis* Blanchard in Gay. Neotype male, fore and hindwings. Forewing lengh = 3.8 mm. Abbreviations: C, costal vein; Sc, subcostal vein; R, radial vein; Rs, radial sector; M, medial vein; Cua, anterior cubital vein; Cup, posterior cubital vein; A1–A3, anal veins.Drawing courtesy of S. Winterton. (4) *Ormiscocerus nitidipennis* Blanchard in Gay. Second male (Punta Molles), fore and hindwings. Drawing courtesy of V. Saxe. (5) *Ormiscocerus nitidipennis* Blanchard in Gay, male terminalia, lateral view. Drawing by N. Penny. (6) *Ormiscocerus nitidipennis* Blanchard in Gay, male genitalia, caudal view. Drawing by N. Penny.

numerous short, dark setae. Mid- and hind coxae much shorter, with sparse dark setae. Front and hind femora pale with dark setal spotting and numerous long dark setae. Middle legs detached from body, one missing. Front and hind tibiae pale, elongate, cylindrical, with numerous long dark setae. Tibial spurs absent. Tarsi with five tarsomeres, basal four tarsomeres pale, apical tarsomere dark, with two small, untoothed tarsal claws.

WINGS.— Forewing length 3.8 mm. Wing membrane gray. Forewing parallel-sided with rounded apex; costal area wide (at widest, one-third of entire wing width); recurrent vein absent; all veins swollen and darkened at wing margin (Figs. 2–3). Longitudinal veins and crossveins pale, with intersections and forks dark. Subcosta (Sc) widely separated from radius (R); with ten subcostal crossveins. One radial sector, with five branches. Anterior media (MA) only one-branched. Posterior media (MP) branched only in apical half. Cubitus (Cu) branched basally. First anal vein (1A) and second anal vein (2A) both branched. Third anal vein (3A) very short, unbranched. Apical crossveins not lined up in clear gradate series. Hindwing widest apically, with three subcostal crossveins. R with two branches. Six R-Rs crossveins. One basal R-M crossvein at origin of radial sector (ORs). Two additional R-M crossveins more distally. M forked slightly distal to level of ORs. Anterior Cu (CuA) unbranched. Posterior Cu (CuP) apically fused with CuA. 1A and 2A only with marginal forks.

ABDOMEN.— Sclerites brown with pleural membrane white; sclerites densely covered with stout dark setae with thick, conical bases. First five sternites with annular groove at mid-length. Eighth and ninth tergites and sternites unfused. Ninth sternite not elongated, unmodified. Ectoprocts not fused, not elongated, not modified, caudal margin evenly rounded.

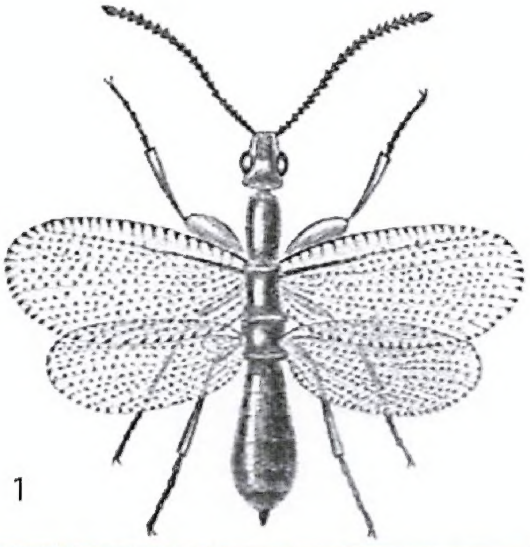
MALE GENITALIA.— Highly simplified, with only two components: a dorsal, vertical, thin arched gonarcus without lobes or expansions, and a pair of ventral, horizontal, thin, elbowed parameres (gonocoxites) that are slightly expanded apically and membranous at the midline (Figs. 5–6). Anteriorly the bases of gonarcus and parameres articulate with one another. Mediuncus absent.

ADDITIONAL MATERIAL STUDIED.— CHILE: **Aconcagua Province**: Punta Molles, first week of November, 1971, 1 male, D. Janzen (E.G. MacLeod Collection, Texas A&M Univ.).

DISCUSSION

The characteristics cited in the original description of *Ormiscocerus nitidipennis* that lead us to believe that the two specimens we have studied represent the same species include the highly reduced number of antennal flagellomeres, the very rounded wings, and the darkened, swollen apices of wing veins. The original drawing appears to show a single radial vein, widely separated from the Sc, but this is open to interpretation. The most striking feature of the neotype (Fig. 2) is the alternating black and white pattern along the wing veins and at the wing margin. This is caused, in part, by the swelling and darkening of the apex of each wing vein. This feature is clearly depicted in Blanchard's original illustration (Fig. 1). The neotype specimen currently before us is certainly more accurately depicted by the original description and illustration than any other form that we have seen, and we have, thus, concluded that this specimen from Quebrada El Arrayán is conspecific with *Ormiscocerus nitidipennis*.

The two studied specimens differ in several respects. The neotype is a relatively recently collected specimen and the alternating black and white pattern of body and wings is striking. The second specimen (Fig. 4) is an older specimen and it shows a less contrasting pattern; it is rather drab brown and apparently faded. The neotype has several more subcostal crossveins than the second specimen, but when crossveins are numerous, variation is usually greater. The forewing vein R_1 of the neotype progresses almost in a straight line to the apical margin, whereas forewing vein R_1 of



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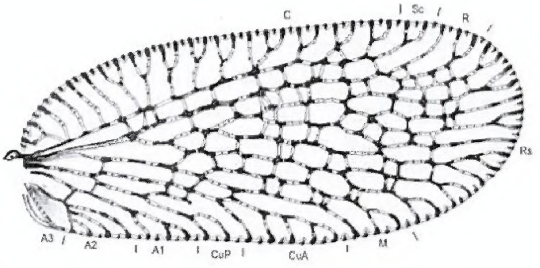
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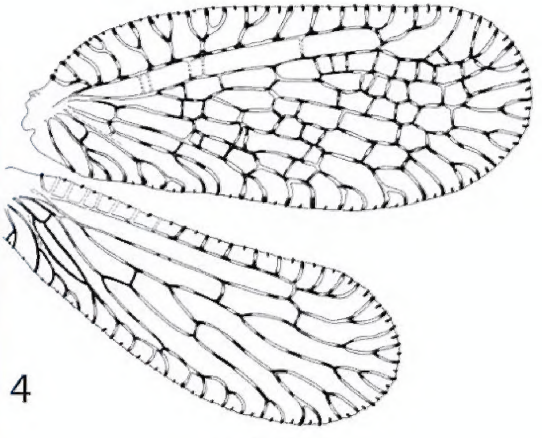

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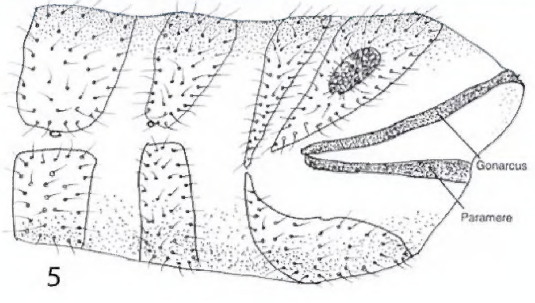
Gonarcus
Paramere

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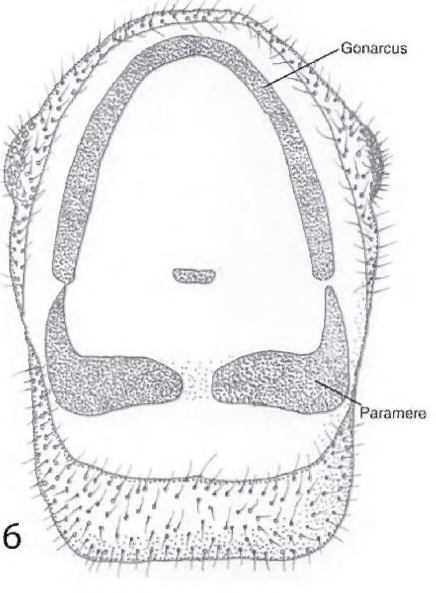
Gonarcus
Paramere

6

and Berothidae together in the same clade with Rhachiberothidae and Mantispidae. The wing shape, presence of trichosors, number of forewing radial sectors, and presence of parameres are all primitive character states that tend to merge in these basal genera making familial placement more difficult. The elongated state of the mediuncus is a derived feature that unites *Cyrenoberotha* (Berothidae) and Platymantispinae (Mantispidae). The presence of raptorial forelegs is a derived state uniting Rhachiberothidae and Mantispidae. The absence of these derived characters, as well as the single radial sector, help define *Ormiscocerus* and it may be considered the most generalized living member of this clade.

Acknowledgments

We would like to thank John D. Oswald for help in locating the Punta Molles specimen of *Ormiscocerus* and for discussion of hemerobiid morphology. We would also thank him for setting up the online Neuroweb site, which makes finding literature and included species so much easier. We wish to thank Victoria Saxe for the wing drawings of the neotype.

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the second specimen dips posteriorly beyond the last subcostal crossvein. The many crossveins and apical twigs have somewhat different placement in the two specimens. These differences individually are not usually significant, but taken in aggregate might signify separate species. On the other hand, because no differences could be found in the male genitalia, we have decided, tentatively, to include the second specimen as a variant of *Ormiscocerus nitidipennis*.

There are several unique characteristics of this species that make it immediately recognizable. The mouthparts are prognathous. The antenna, with scape, pedicel, and flagellum consists of only 20 segments. The pronotum is quadrate and longer than wide. Wings are short, broad, and apically rounded, with large nodules at the ends of the veins. Most distinctive are the single radial sector in the forewing and the simplified elements of the male genitalia.

On the other hand, some features that appear in the original description and habitus drawing are not present in our specimens: the antennae are inserted between the eyes, not farther forward on the frons; the pronotum is not as elongate as depicted in the original illustration; the forecoxae are not greatly swollen, but rather are normally enlarged, as with other berothids; and the abdomen is cylindrical, not expanded caudally. These apparent discrepancies may be attributable to the small size and somewhat "stylized" rendering of the original drawing.

Superficially, this form appears similar to species of *Nusalala* that have been described from high altitudes in Colombia (Penny and Sturm 1984) and Costa Rica (Oswald 1997) in that the wings are small, short and rounded with reduced recurrent vein, the veins are thickened, and the gradate series are not well aligned. However, the prognathous mouthparts, single radial sector and thin, unelaborated gonarcus and parameres and lack of a developed mediuncus clearly place this species in another group.

Only one species of hemerobiid, *Adelphohemerobius enigmaramus* Oswald, has a single radial sector. It is a much larger form with recurrent vein, distally tapered wings and no swelling of vein apices. Only a single female of *A. enigmaramus* is known, so that terminalia cannot be compared. Oswald (1994) considered it to be the most primitive hemerobiid known at the time and placed it in a separate subfamily, the Adelphohemerobiinae. Oswald also considered placing *Adelphohemerobius* in a separate family but decided that "its possession of a habitus generally similar to that of other hemerobiids (e.g., in size, coloration, wing shape and body form), as well as its possession of several of the autapomorphies attributed by Oswald (1993a) to the hemerobiid stem lineage (i.e., the stem of the clade Hemerobiidae), argue for its inclusion in a slightly expanded concept of the Hemerobiidae." (Oswald 1994:300–301)

The prognathous mouthparts, trichosors and setal tufts of the wings, the hindwing with oblique sinuous piece of MA, and especially the male genital elements suggest that *Ormiscocerus* belongs in the berothid subfamily Cyrenoberothidae. The separation of the male ninth tergum from the ectoproct and distinct presence of lateral parameres are significant.

Although *Berothimerobius reticulatus* (tentatively placed in Hemerobiidae) has a second radial sector, which is not normally found in Berothidae, the wing shape, size, and venation are similar to that of *Ormiscocerus nitidipennis*. Illustrations of the female genitalia of *B. reticulatus* (Monserrat and Deretsky 1999, figs. 34–35) are similar to illustrations of female genitalia of *Cyrenoberotha penai* (MacLeod and Adams 1967; figs. 15–16). Although it is not possible to compare head and antennae of the two forms, it seems probable that *Berothimerobius* and *Ormiscocerus* are closely related and belong in the berothid subfamily Cyrenoberothinae.

All four of the mentioned genera are known only from Chile and *Adelphohemerobius*, *Berothimerobius* and *Ormiscocerus* are known from a combined total of only four specimens (excluding the original type of *Ormiscocerus*).

Recent studies of neuropteran phylogeny (Aspöck 2001; Winterton 2003) place Hemerobiidae

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Seasonal Emergence of Neuroptera in Fairfax County, Virginia

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A total of 419 specimens, 25 species, and eight families of Neuroptera were collected from 81 light trap sites in Fairfax County, Virginia, during 2005. Eighty percent of the species (20 of 25) belong to the families Chrysopidae, Coniopterygidae, and Hemerobiidae. The most commonly collected species was the green lacewing, *Chrysoperla rufilabris* (Burmeister), with 29% of the specimens. First records for the state of Virginia are noted for *Hemerobius pinidumus* Fitch and *Hemerobius stigma* Stephens. These data provide a baseline for monitoring future climate change in the metropolitan Washington, D.C. area.

Neuroptera are among our most beneficial insects. Larvae are predators of other insects and can consume a wide variety of insect eggs, nymphs, larvae, and adults (Tjeder 1966) in a variety of habitats and ecological niches. Many move actively over the foliage feeding on almost any insect of the appropriate size. Neuropterans are released in agricultural lands to augment naturally occurring field populations, and are reared for release more than any other group of beneficial insects (Tauber, M.J. et al. 2000). Larvae of antlions are sedentary predators living in tree holes, on the soil surface, and in specialized pits that they create in loose soil (Stange 2004). Larvae of mantis-flies are mostly predators on spider egg sacs (Redborg 1998). Berothid larvae live in termite nests and feed on the termites (Tauber, C.A., and M.J. Tauber 1968). The only aquatic family of neuropterans in North America, the Sisyridae, feed on freshwater sponges as larvae (Parfin and Gurney 1956).

Neuropterans are plentiful in the urban environment. Adults are nocturnal and chrysopids and hemerobiids can frequently be seen at window panes and store fronts at night. In the eastern United States their adult taxonomy, geographical distributions, and diapause mechanisms are fairly well understood (Penny et al. 1997; Tauber, M.J., and C.A. Tauber 1976), yet relatively few studies have been carried out on seasonal activity patterns. With the growing evidence that humans are impacting the environment and are a major contributor to climate change (Hansen and Lacis 1990; Walther et al. 2002), we need to understand baseline patterns of seasonal variation in insect populations. To investigate seasonal patterns of neuropterans in the Mid-Atlantic States, we analyzed collections from a series small light traps set up at 81 sites in Fairfax County, Virginia, in 2005. The light traps were used to monitor mosquito populations and throughout the warmer seasons were also utilized to monitor adult neuropteran presence.

Materials and Methods

Beginning in early May of 2005, one standard Centers for Disease Control and Prevention (CDC) miniature light trap (Sudia and Chamberlain 1962) was set overnight at each of 72 sites once

a week for 24 weeks as part of the mosquito surveillance activities conducted by the Fairfax County Disease Carrying Insects Program. Trap sites were located throughout Fairfax County in areas of varying habitat. In mid-June these trapping efforts were complemented by an additional nine sites (Fig. 1). This technique is useful for the collection of adult Neuroptera, as most species are phototropic insects. However, as the primary purpose of these traps was to collect adult mosquitoes, each trap was also baited with carbon dioxide (CO_2) to increase mosquito numbers and diversity.

The body of the CDC miniature light trap was Plexiglas tubing, which housed a 6.3 volt light bulb, a DC motor, and fan blade. A motorcycle, lead-acid, six-volt battery provided the necessary power. A detachable, flat-topped, plastic lid covered the body of the trap to protect the operating mechanism (Fig. 2). Insects attracted to the light were sucked through the fan blade into a fine mesh collection cup that hung from the bottom of the tubing. Trap sites were typically located a short distance into the margins of wooded areas where cover was good and other sources of artificial light could be avoided. Traps and accompanying plastic thermoses containing dry ice, as a source of CO_2, were hung from trees approximately 1.5 m above the ground.

Throughout the season 1,859 trap samples were examined for neuropterans. All insects were collected alive and killed with triethylamide in the laboratory. Neuropterans observed while sorting trap collections for mosquitoes were removed and assigned specimen identification numbers. Coniopterygidae were preserved in 80% ethanol whereas other neuropterans were dry packed. All specimens in this study are deposited at the California Academy of Sciences. Temporal distribution of these species throughout Fairfax County was determined. The closely related order Megaloptera was not included in this study. A recent study of seasonal populations of the megalopteran family Sialidae in coastal Virginia can be found in Barrows et al. 2005.

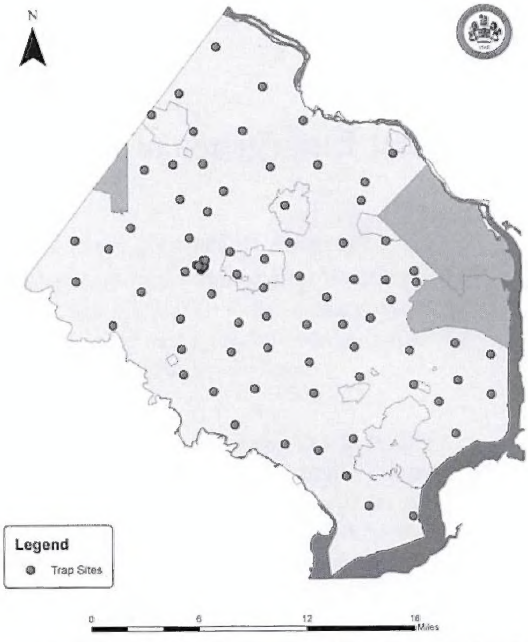


FIGURE 1. Map of collecting localities in Fairfax County, Virginia.

FIGURE 2. CDC miniature light trap.

RESULTS

A total of 419 specimens of 25 species in eight families were found in the samples from Fairfax County. Almost 96% of the specimens belonged to three families: Chrysopidae, Coniopterygidae, and Hemerobiidae. No more than seven specimens were encountered of any of the other five families collected.

Family Chrysopidae

Larvae of green lacewings feed on a wide variety of insects that they capture on vegetation, but are best known for feeding on relatively sedentary homopterous pests. Hence, the common name of aphid-lions. Some larvae, such as *Ceraeochrysa lineaticornis*, cover their bodies with debris and the bodies of their prey (Tauber, C.A. et al. 2000). Individuals of this family were the most plentiful, especially during the middle of the summer. In all, six species in four genera were encountered in the light traps.

***Ceraeochrysa lineaticornis* (Fitch, 1855)**

This is a generalist feeder that is found at forest edges and within open forests. Seven specimens were captured, most of them during August and September (Fig. 3).

***Chrysopa oculata* Say, 1839**

This is perhaps the most widespread species of green lacewing in North America. It has a transcontinental distribution and can be found from sea level up to 2576 m (8500 ft.) in elevation. This species is most frequently found in open areas, such as fields and roadside ditches. In Fairfax County its adult population continued to increase throughout the summer and peaked in mid-September (Fig. 4).

***Chrysopa quadripunctata* Burmeister, 1839**

This distinctive species has four bright orange spots on the pronotun that make it easily separable from all other species except *C. slossonae*. Unfortunately, these spots frequently fade after death making recognition more difficult. Although *C. slossonae* is found in Virginia (Penny et al. 1997), it was not encountered during this study. *C. quadripunctata* larvae are generalist predators, while larvae of *C. slossonae* are highly specialized feeders on wooly alder aphids, *Prociphilis tesselatus* (Fitch) (Tauber, C.A. et al. 1995). *C. quadripunctata* adults were found throughout the season, but were more abundant in September (Fig. 5).

***Chrysoperla rufilabris* (Burmeister, 1839)**

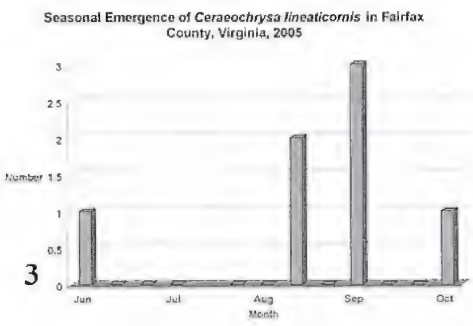
This species prefers trees, especially in open environments such as orchards, parks, and yards. This is the most abundant species in residential areas of the eastern coastal region and was the most commonly encountered species in the survey. It appeared to reach peak abundance in August (Fig. 6)

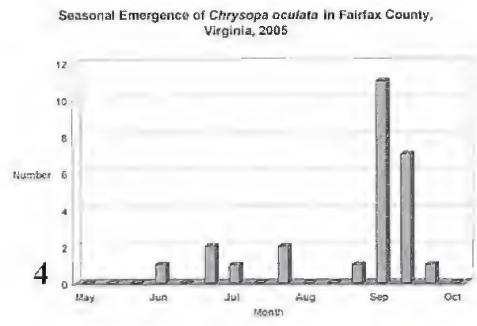
***Leucochrysa (Leucochrysa) insularis* (Walker, 1853)**

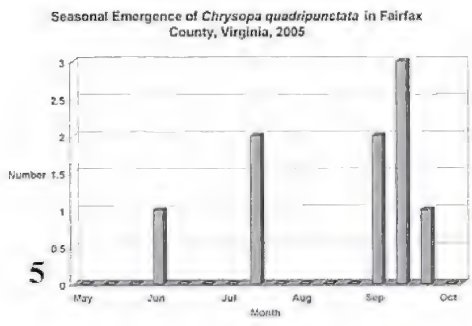
This is the largest species of green lacewing found in the Fairfax County area. It is widespread from Massachusetts to Florida and Iowa to Arkansas (Penny et al. 1997). It is a woodland species that is seldom seen outside of forests. Six individuals were captured on June 23, July 9 [2], July 21, August 5, and September 1. This species appears to be present in low numbers, at least during the period of the survey (Fig. 7).

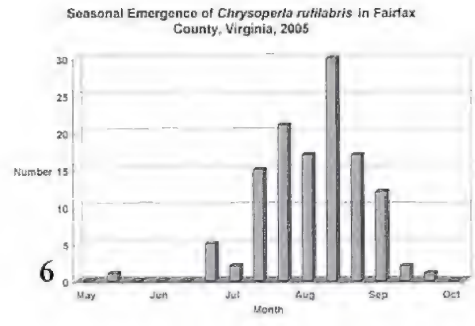
***Leucochrysa (Nodita) pavida* (Hagen, 1861)**

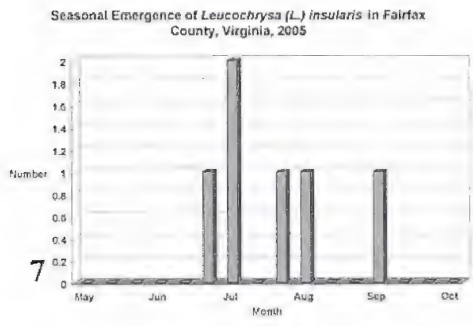
As with the preceding species, this species of *Leucochrysa* is a woodland species and relative-

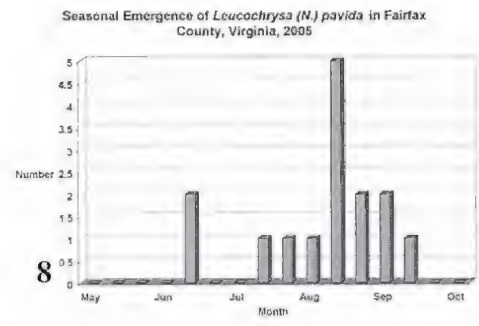












FIGURES 3–8. Seasonal captures of Chrysopidae. Figure 3 – *Ceraeochrysa lineaticornis*: Figure 4 – *Chrysopa oculata*: Figure 5 – *Chrysopa quadripunctata*: Figure 6 – *Chrysoperla rufilabris*; Figure 7 – *Leucochrysa* (*L.*) *insularis*; Figure 8 – *Leucochrysa* (*N.*) *pavida*.

ly large. There appears to be a close relationship between lichens and larvae of this species (Slocum and Lawrey 1976). Larvae occur on the trunks of a wide variety of trees bearing these commensals and cover their bodies with packets of lichens. Adults rest on leaves of a variety of deciduous trees (Tauber, C.A. 2004). They are a more tropical species and Fairfax County is near the northern limit of their distribution. Fifteen individuals were captured between 16 June and 14 September with an apparent peak in late August (Fig. 8).

Family Hemerobiidae

The brown lacewings were the most speciose family in the traps, with eight species in four genera. All of the collected species have ample distributions, being found throughout the eastern U.S. Adults appear to avoid the warmest periods of summer and are most prevalent in September, with a secondary peak in June.

***Hemerobius humulinus* Linnaeus, 1758**

This is the most abundant hemerobiid in eastern North America. It is also found in Western Europe. Adults are frequently encountered on deciduous trees where both larvae and adults feed on slow-moving, soft-bodied insects. In the Fairfax County area, adults have a bimodal emergence in May-June and again in late August and September (Fig. 9).

***Hemerobius pinidumus* Fitch, 1855 (New state record)**

This is a northern species having previously only been recorded as far south as New Jersey (Penny et. al 1997). Thus, this is the first record for this species from Virginia. Only a single individual was captured on September 21. It may be a late-season emergent in the southern part of its distribution.

***Hemerobius stigma* Stevens, 1836 (New state record)**

This species is the counterpart of *H. humulinus* on conifers. It is almost never seen on deciduous trees. It has an ample distribution in Western Europe and throughout the northern and mountainous parts of North America. Only a single specimen was collected before September, perhaps indicating a low population of adults early in the year and a larger fall emergence (Fig. 10). This is the first record for this species from Virginia.

***Megalomus fidelis* (Banks, 1897)**

This was the only species of *Megalomus* encountered during the study, and one of the least collected species of Hemerobiidae. This species was only encountered three times from mid-August to early September (Fig. 26).

***Micromus posticus* (Walker, 1853)**

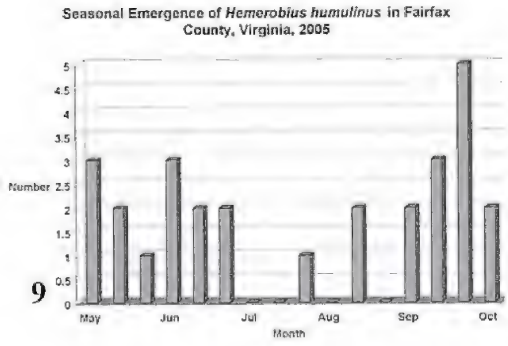
This is the most frequently collected hemerobiid in the survey. It is found in forests in the eastern part of the country. Although collections indicate a typical hemerobiid bimodal emergence, some adults were trapped throughout the season, indicating a continuous (albeit low population level) presence of adults (Fig. 11).

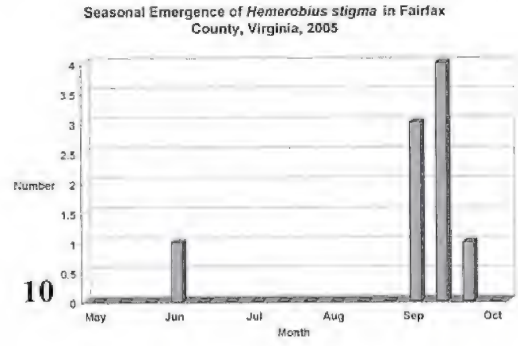
***Micromus subanticus* (Walker, 1853)**

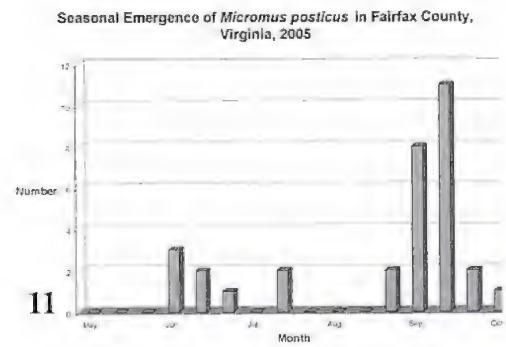
This species is found in open grassland. Numbers were low in traps, probably because of a forest habitat preference for trap locations. As with most hemerobiids, trapping levels were low until September (Fig. 12).

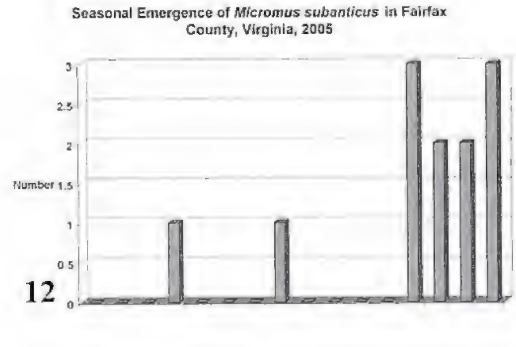
***Sympherobius amiculus* (Fitch, 1855)**

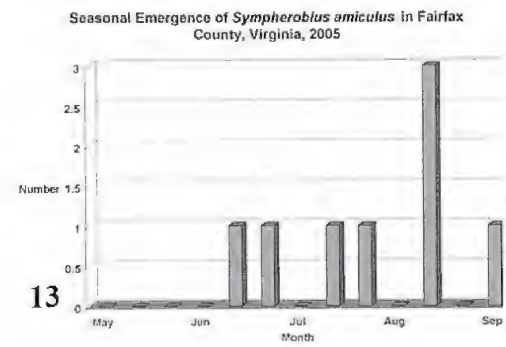
The species of *Sympherobius* are among our smallest brown lacewings. *S. amiculus* is the most common species of *Sympherobius* in southeastern Canada and the eastern U.S.A. west to about the 100th meridian. It has been found associated with various species of pine, oak, apple, and vineyards (Oswald 1988). Adults have been collected from January 15 to November 11 (Oswald *ibid.*) and during this survey were collected from June 15 to September 20, with a gradual increase in numbers until late August and early September (Fig. 13).

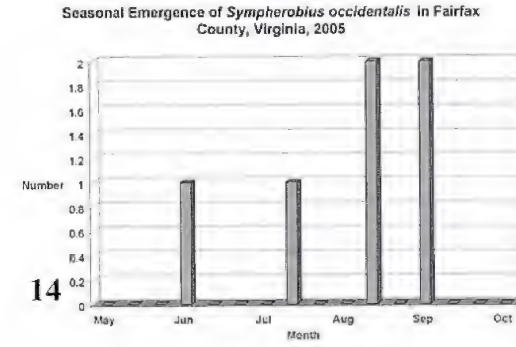












FIGURES 9–14. Seasonal captures of Hemerobiidae. Figure 9 – *Hemerobius humulinus*; Figure 10 – *Hemerobius stigma*; Figure 11 – *Micromus posticus*; Figure 12 – *Micromus subanticus*; Figure 13 – *Sympherobius amiculus*; Figure 14 – *Sympherobius occidentalis*.

Sympherobius occidentalis (Fitch, 1855)

This species has been associated with *Pinus* sp. throughout the eastern U.S.A. and collected elsewhere from April 20 to October 25 (Oswald 1988). but our survey found a gradual increase in numbers from June 8 to September 9 (Fig. 14).

Family Coniopterygidae

Coniopterygidae, or dustywings, are tiny neuropterans that feed on soft-bodied, slow moving insects, especially homopterans. Adults are completely covered with a fine white powder that gives them the appearance of whiteflies (Homoptera: Aleyrodidae). Perhaps it is no accident that whiteflies are among the favorite food items of this family. They are normally nocturnal, and adults can often be seen fluttering among bushes and shrubbery early on warm mornings. Later in the day they rest under leaves and are much harder to find (NP, personal observation). Six species in three genera were collected in Fairfax County during the study. Females cannot be separated from other species of the same genus, so that counts are based on males only, unless females are associated with males in the same trap sample.

***Coniopteryx (Coniopteryx) simplicior* Meinander, 1972**

This species is found throughout the eastern U.S.A. and has been recorded on peach and *Citrus* trees. Seven specimens of this species were collected, five on July 13 at one trap site. There may have been a temporary colony of host prey near the trap site at this time (Fig. 15).

***Coniopteryx (Coniopteryx) tineiformis* Curtis, 1834**

This is a widely distributed species, being found in Europe, Asia Minor, and northern North America (Meinander 1972). It is confined to deciduous trees and bushes (Meinander *ibid.*). During the study, it was only collected twice, both late in the season, on September 1 and September 13 (Fig. 16).

***Coniopteryx (Coniopteryx) westwoodi* (Fitch, 1855)**

This species is found throughout the eastern U.S.A. and is the most common species of dustywing in the Fairfax County area. There appears to be an early summer emergence and then a larger emergence in August and September (Fig. 17).

***Conwentzia pineticola* Enderlein, 1905**

This is the most widely distributed species of coniopterygid in the study. It is found throughout Europe and eastern North America, North Africa, Siberia, and Mongolia (Meinander 1972). It is typical of many species of *Conwentzia* in that its hindwings are reduced to small stubs, and it is functionally two-winged. Both larvae and adults are found primarily on coniferous trees (Meinander 1972). There appears to be a June emergence that tapers off later in the season (Fig. 18).

***Semidalis inconspicua* Meinander, 1972**

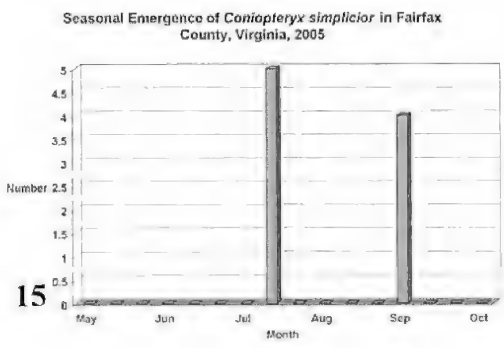
This species has been collected on *Carya*, *Quercus*, and *Juniperus*. Although it is hard to generalize from only two trap captures, both records are for September (Fig. 19).

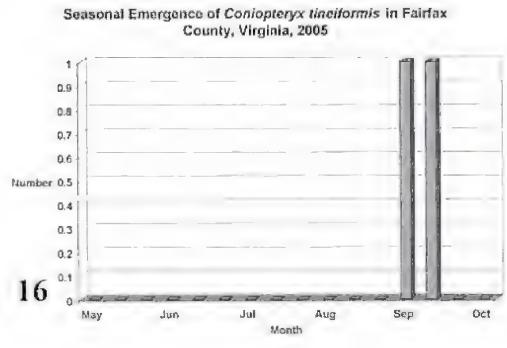
***Semidalis vicina* (Hagen, 1861)**

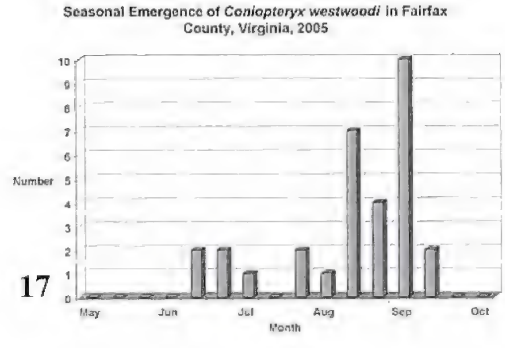
This species is found in Europe, Morocco, and the eastern U.S.A. It has been recorded on deciduous trees such as elm, oak, and peach, as well as orange trees. Muma (1967) records it as feeding on homopterous insects and mites. It appears to emerge as adults in early summer and continues to be present in low numbers throughout the summer and early fall (Fig. 20).

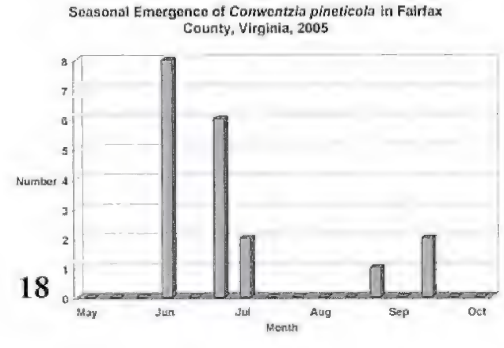
Family Berothidae

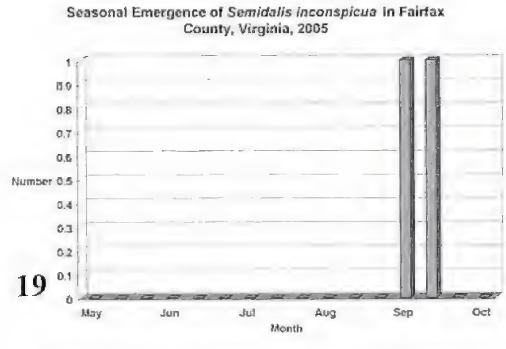
This family, called beaded lacewings, is quite distinctive. The only genus in North America, *Lomamyia*, has adults with falcate (scalloped) wings. Females often have scales on the thorax,

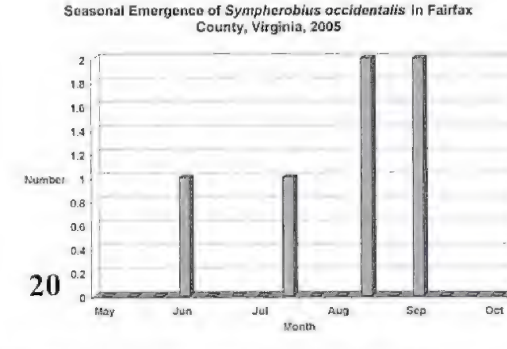










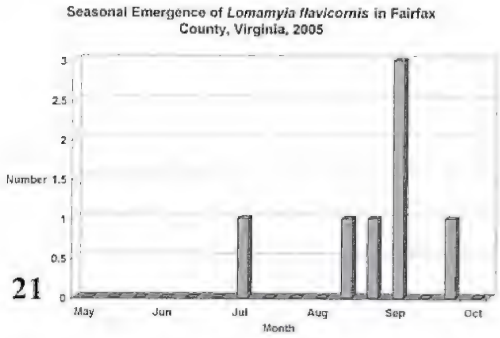


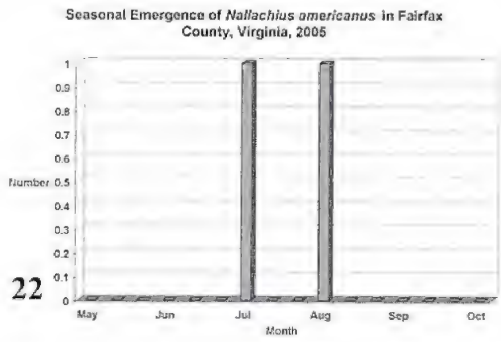
FIGURES 15–20. Seasonal captures of Coniopterygidae. Figure 15 – *Coniopteryx* (*C.*) *simplicior*; Figure 16 – *Coniopteryx* (*C.*) *tineiformis*; Figure 17 – *Coniopteryx westwoodi*; Figure 18 – *Conwentzia pineticola*; Figure 19 – *Semidalis inconspicua*; Figure 20 – *Semidalis vicina*.

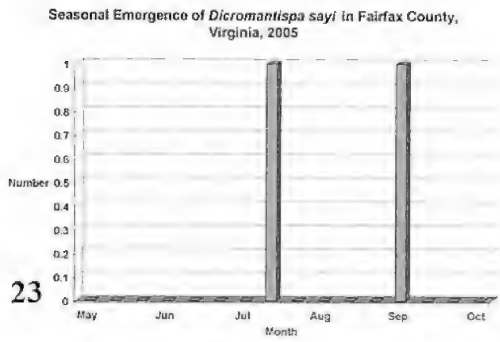
coxae, or along the wing veins. When resting on twigs or plant stems, adults weave back and forth, as if being blown in the wind (NP, personal observation). Larvae live in termite nests where they feed on termites and appear to be completely accepted by the colony (Tauber, C.A., and M.J. Tauber 1968; Johnson and Hagen 1981).

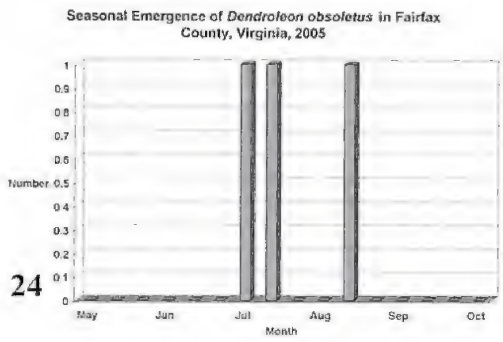
***Lomamyia flavicornis* (Walker, 1853)**

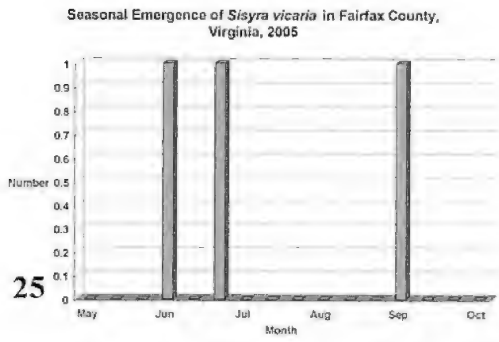
This species is found throughout the eastern U.S.A. as far west as Kansas wherever termites are found. In Fairfax County, most adults were collected in late August and early September (Fig. 21)

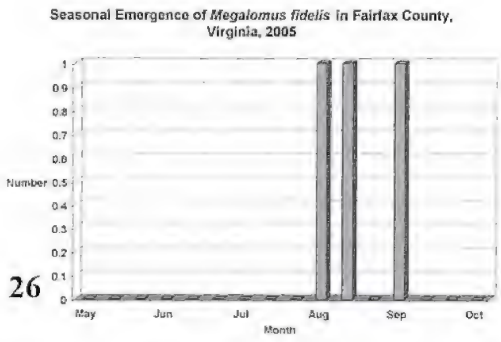












FIGURES 21– 26. Seasonal captures of various Neuroptera. Figure 21 – *Lomamyia flavicornis* (Berothidae); Figure 22 – *Nallachius americanus* (Dilaridae); Figure 23 – *Dicromantispa sayi* (Mantispidae); Figure 24 – *Dendroleon obsoletus* (Myrmeleontidae); Figure 25 – *Sisyra vicaria* (Sisyridae); Figure 26 – *Megalomus fidelis* (Hemerobiidae).

Family Dilaridae

Dilaridae are known as pleasing lacewings. Adults are relatively small, hairy, and broad-winged. Usually there are dark bands across the wings. Females have elongate ovipositors and males have plumose antennae, making them look much like small moths. Larvae are predators of insects living in rotting logs (MacLeod and Spiegler 1961). Only two species are known from the U.S.A., one living in the East and the other in the Southwest (Penny et al. 1997).

***Nallachius americanus* (McLachlan, 1881)**

This species is found in the eastern U.S.A. from Indiana to Georgia. Two males were collected on 6 July and 3 August (Fig. 22).

Family Mantispidae

Mantispids are called mantis-flies because of their close resemblance to small praying mantids. Larvae are generally known as spider egg case predators, but some larvae feed on solitary wasps, colonial wasps, and even scarab pupae in the soil (MacLeod and Redborg 1982). One female will lay thousands of eggs, often in clusters on the bark of trees. The first instar larvae are elongate and active, seeking to board a female spider before she forms her egg sac. Because the chances of success are so small, the number of eggs laid must be great (Redborg and MacLeod 1985). The second and third instar larvae are scarabaciform and sedentary inside the egg sac of the host. Because the food source for larvae is fixed and finite, mantispids are one of the few groups of insects that can survive food shortages by producing a much smaller adult.

This is a small family with only 15 species known from the U.S.A., most of them confined to the southwestern part of the country.

***Dicromantispa sayi* (Banks, 1897)**

This species is widespread in the southern U.S.A. from Georgia and Florida to Arizona and as far north as Illinois. Two individuals were captured during the study, on July 12 and September 7 (Fig. 23).

Family Myrmeleontidae

Myrmeleontidae, or ant-lions, is the largest family of Neuroptera worldwide with more than 1200 described species (Stange 2004). Ninty-four species are known from the United States (Penny et al. 1997) with most of them distributed in the desert Southwest.

Dendroleon is a colorful genus with two species, one eastern and one western, both bearing numerous dark maculations on the wings. The eastern species, *Dendroleon obsoletus*, was captured during the study in Fairfax County.

***Dendroleon obsoletus* (Say, 1839)**

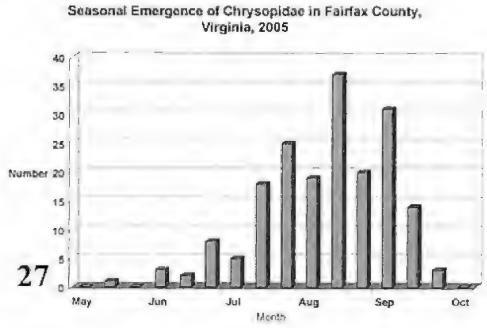
This species is widespread over the eastern U.S.A. as far west as Kansas (Penny et al. 1997). It is known to live in tree holes as larvae (Stange 1980). Two adults were captured on July 14 and August 11 (Fig. 24).

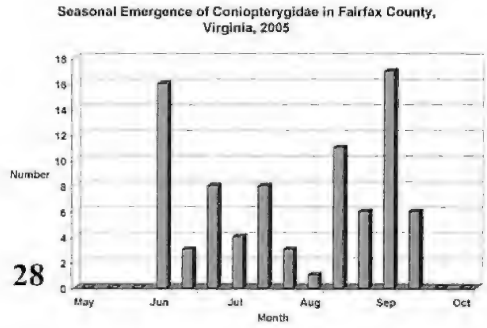
Family Sisyridae

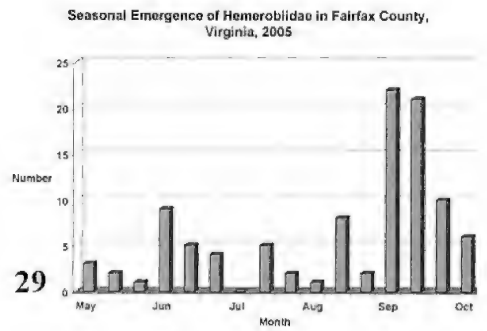
This is the only truly aquatic family of Neuroptera in North America. Larvae live in fresh or brackish water and feed on freshwater sponges. When mature, larvae climb out of the water and pupate at the top of rushes or on the bark of trees. Larvae often weave an inner cocoon and a loose outer webbing (Parfin and Gurney 1956). Although associated with water, adults can often be captured several hundred feet in the air or more than a kilometer from the nearest water course (NP, pers. obser.).

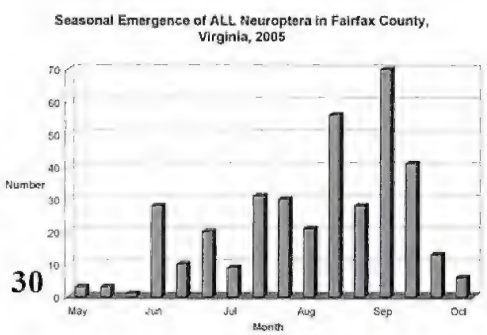
***Sisyra vicaria* (Walker, 1853)**

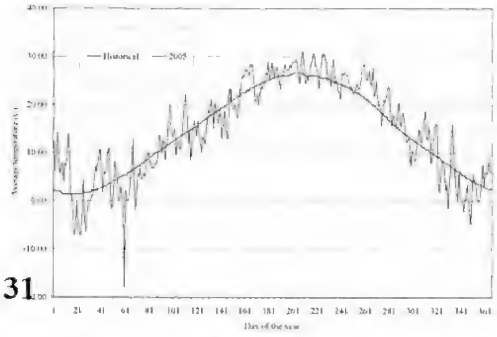
This species is found throughout North America. During the study three individuals were captured on June 8, June 28, and September 1 (Fig. 25).

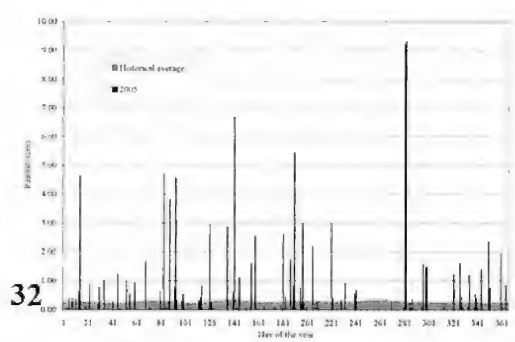












FIGURES 27–32. Total seasonal captures of all Chrysopidae (Figure 27); all Coniopterygidae (Figure 28); all Hemerobiidae (Figure 29); and all Neuroptera (Figure 30). Figure 31: Seasonal temperature pattern in Fairfax County. Figure 32: Seasonal rainfall pattern in Fairfax County.

DISCUSSION

The seasonal life cycle of predatory neuropterans is controlled by both climatic factors such as photoperiod and temperature and biotic factors such as abundance of food. Whether a second generation per year is produced, or not, is based on a balance of these factors and is constantly adjusted through environmental cues (Canard 2005). Most North American green lacewings overwinter as prepupae in the cocoon, although *Chrysoperla* species overwinter as adults (Canard *ibid.*). Several species of North American Hemerobiidae are found overwintering in cocoons within conifer cones (Deyrup and Deyrup 1978). Springtime rising temperatures and longer photoperiods trigger a break of diapause and a renewal of feeding and reproductive activity (Canard 2005). Most

chrysopids are facultatively multivoltine and by early summer the longer day length, as well as biotic factors, such as the abundance of aphids determine whether the species undergoes multiple generations, or not (Canard *ibid*). As the days get shorter in the fall, the shorter photoperiod and lower temperatures work differentially on the larvae to stop development. This helps synchronize the renewed development and adult emergence the following spring (Canard *ibid.*).

The overall abundance of adult neuropterans increased throughout the summer months until the colder, shorter days of late September and early October (Fig. 30). However, the various families behaved differently. In Fairfax County, Chrysopidae reached maximum population levels in August (Fig. 27), while Hemerobiidae reached their highest levels in mid to late September (Fig. 29). Coniopterygidae appeared to be more balanced, with emergence occurring throughout the warmer months (Fig. 28). This separation of emergences may be one way of partitioning similar food prey, as most species of all three families glean various stages of soft-bodied insects from plant surfaces. The interplay among food specialization, habitat selection, and emergence partitioning may provide the niche breadth needed for survival in the suburban Virginia environment. It is unknown what impact changing temperature (Fig. 31) and rainfall patterns (Fig. 32) will have on development and emergence patterns of these insects in the future.

A more extensive survey should be conducted not only to verify but to enhance the baseline data provided here inasmuch as altering patterns of Neuroptera emergence and population densities seem to be closely tied to pertubations in local climates, especially in densely populated metropolitan areas such as Washington, D.C. and adjacent communities.

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Synaphridae of Madagascar (Araneae: Araneoidea): A New Family Record for the Afrotropical Region

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The spider family Synaphridae is reported for the first time from Madagascar. Three new species are described. *Africepheia* gen. nov. is established for *A. madagascariensis* sp. nov.; two species of *Synaphris* Simon, 1894 are described: *S. schlingeri* sp. nov. and *S. toliara* sp. nov. Diagnostic characteristics for the family and putative synapomorphies are discussed, elucidated by scanning electron microscope images representing both Malagasy genera. This research highlights the connection between large scale collecting efforts in biodiversity hotspots like Madagascar and advances in systematics.

KEYWORDS: taxonomy, synapomorphy, scanning electron microscopy, *Africepheia, Cepheia, Synaphris*

Synaphrids are tiny, old world, sheet-web building spiders (Marusik et al. 2005; Marusik and Lehtinen 2003; Schütt 2003). Although the precise circumscription and even taxonomic rank of the group remains controversial (Marusik and Lehtinen 2003; Platnick 2007; Schütt 2003; Wunderlich 2004), synaphrids have been subjected to detailed morphological study (Lopardo and Hormiga, in press; Lopardo et al. 2007; Marusik et al. 2005; Marusik and Lehtinen 2003) and placed phylogenetically among related families (Schütt 2003).

Although the first synaphrid described was from Egypt, the family has never been reported from Madagascar or sub-Saharan continental Africa (Dippenaar-Schoeman and Jocqué 1997; Platnick 2007). *Synaphris* is known from the Canary Islands, the Mediterranean region, and Central Asia; *Cepheia* is a monotypic genus from Southern Europe. New species from Madagascar representing *Synaphris* and a new genus are described here.

The spider fauna of Madagascar remains rich, highly endemic, and understudied (Griswold 2003; Legendre 1972). It includes the endemic spider family Halidae (Jocqué 1994), and major endemic portions of the families Archaeidae (Forster and Platnick 1984), Cyatholipidae (Griswold 2001), Gallieniellidae (Platnick 1984), Migidae (Griswold and Ledford 2001), and Phyxelididae (Griswold 1990) among others. Madagascar remains a hotspot for arachnological discovery (e.g., Agnarsson 2006; Agnarsson and Kuntner 2005; Huber 2003; Miller 2006; Silva-Dávila 2005, 2007 [this issue]).

METHODS

All measurements are in millimeters and were taken using a reticule in a Leica MZ12.5 dissecting microscope. Total length measurements (front of clypeus to posterior of abdomen) are approximate and may be influenced by the angle the abdomen is held at and changes in the size of the abdomen due to preservation artifacts. Carapace measurements were made in dorsal view. Leg

articles were measured in lateral view along the dorsal margin. Metatarsal trichobothrium position (Tm position) is expressed as the ratio of the distance between the proximal margin of the metatarsus and the root of the trichobothrium divided by the total length of the metatarsus (Denis 1949; Locket and Millidge 1953).

Somatic illustrations were based on digital photographs taken with a Nikon DXM 1200 digital camera mounted on a Leica MZ16 dissecting microscope. Genitalia were cleared in methyl salicylate (Holm 1979), slide mounted (Coddington 1983), and illustrated using a Leica DM4000 M compound microscope fitted with a drawing tube. Illustrations were rendered in Adobe Photoshop (version 6.0). Photographs of cleared genitalia were taken using a DXM 1200 digital camera mounted on a Leica DM4000 M; multiple images were combined using Auto-Montage (version 5.01).

For examination of the respiratory system, abdomens were digested in warm potassium hydroxide. Digested abdomens were stained with chlorazol black, washed in distilled water, examined in lactic acid using a temporary slide mount (Hormiga 1994), and illustrated using a drawing tube on a Leica DM4000 M microscope.

SEM images were taken using the Leo 1450VP at the California Academy of Sciences. Specimens for SEM examination were air-dried and sputter coated with gold-palladium. Specimens were mounted on copper wire using white glue.

SEMs and illustrations of the male genitalia were either made from the left palp or reversed so they appear to depict the left palp.

All specimens examined are deposited in the California Academy of Sciences (CAS). No synaphrids from beyond Madagascar were examined for this study. Comparisons with other taxa were drawn based on images and descriptions from publications and manuscripts.

Abbreviations and Conventions.— References to figures published elsewhere are listed in lowercase type (fig.); references to figures in this paper are listed with an initial capital (Fig.).

Abbreviations used in the text and figures are given in Table 1. The table also includes abbreviations for putatively homologous structures of the male palp used elsewhere (Lopardo and Hormiga, in press; Lopardo et al. 2007; Marusik et al. 2005). Anatomical terminology for the male palp should be interpreted as implying homology only within Synaphridae; assessment of homology with other spiders (especially symphytognathoids and other araneoids) must await a broader comparative study.

For material examined, when multiple consecutive records were from the same locality, the locality data after the first record is given in brackets as [same locality].

Taxonomy

Family Synaphridae Wunderlich, 1986

Synaphrinae (Anapidae) Wunderlich 1986:113; 1987:137; 1995a:775; 2004:1080.
Synaphridae Marusik and Lehtinen 2003:144. Lopardo, Hormiga and Melic 2007:11.

Diagnosis.— Distinguished from all other spiders by the constriction at the tarsus-metatarsus joint (Figs. 12, 44; Lopardo and Hormiga, in press; Lopardo et al. 2007); distinguished from most araneoids (except symphytognatids and most anapids, micropholcommatids, and mysmenids) by the tracheate anterior respiratory system; further distinguished from most other araneoids (except some theridiids and possibly *Iardinis* and *Crassignatha*) by having the chelicerae armed only with an anterior keel (Figs. 11, 47). Unlike other araneoids, synaphrids may have the tarsi divided into two pseudosegments (Fig. 13; Marusik et al. 2005; but see Lopardo and Hormiga, in press; Lopardo et al. 2007). The strong groove connecting the posterior tracheal spiracles (Fig. 61) is reminiscent

of Cyatholipidae (Griswold 2001: fig. 22C) and the micropholcommatid genus *Teutoniella* (Platnick and Forster 1986: fig. 9).

Description.— Small (ca. 1 mm) eight-eyed, three clawed, ecribellate, entelegyne spiders. Carapace longer than wide to nearly round (Figs. 3, 37; Thaler and Noflatscher 1990: fig. 29), median row of setae with enlarged bases (Marusik et al. 2005: fig. 22). Eyes subequal, evenly spaced in two rows, lateral eyes juxtaposed (Fig. 42). Chelicerae with anterior keel, no other teeth (Figs. 11, 53). No enlarged cheliceral gland mound or peg teeth (Fig. 47). Labrum without anterior spur (Fig. 46). Labium fused to sternum (Schütt 2003), not rebordered. Posterior margin of sternum truncated (Figs. 4, 38). Patellae with one long dorsal macroseta; no other leg macrosetae. Tibiae with long trichobothria, metatarsi I and II each with one trichobothrium; bothria hooded (Figs. 14–15, 50–51); tibial bothria occasionally modified with a deep central notch and small pit (Marusik and Lehtinen 2003: fig. 23). Metatarsi tapered distally with large dorsal lyriform organ (Figs. 12, 44). Tarsi sometimes divided into two pseudosegments (Fig. 13; but see Lopardo and Hormiga, in press; Lopardo et al. 2007), teeth on major tarsal claws variable (Fig. 13; Marusik et al. 2005: figs. 25, 29, 32; Marusik and Lehtinen 2003: fig. 19); inferior claw with dorsal denticle (Fig. 13; Lopardo et al. 2007). Tarsal organ small, round, flush with surrounding cuticle (i.e., not raised; Figs. 16, 52; Schütt 2003; Marusik and Lehtinen 2003), located on proximal half of tarsus. Anterior respiratory system tracheate with some tubes passing into the prosoma (Fig. 8); vestigial book lung covers present (Figs. 1, 35); posterior tracheae with a pair of widely-spaced spiracles connected by a deep groove advanced from the spinnerets about ⅕ the distance to the epigastric furrow (Fig. 61). Tracheae with two trunks branching into numerous tracheoles, some of which pass through the pedicel into the prosoma (Fig. 8). Male with 3–4 epiandrous gland spigots (Figs. 26, 62, 75). Colulus present (Fig. 29). ALS with a major ampullate gland spigot, one tartipore, one nubbin, and

Table 1: List of anatomical abbreviations used in the text and figures with abbreviations of putatively homologous structures of the male palp used elsewhere.

Male palp:

C	conductor
CA	terminal apophysis of conductor (= SA of Marusik et al. 2005; Cap of Lopardo and Hormiga, in press; Lopardo et al., in press)
CB	cymbium
CG	groove of conductor (= TG of Marusik et al. 2005)
CM	membranous part of cymbium (= Ct of Marusik et al. 2005)
CT	tip of conductor (= TA of Marusik et al. 2005)
E	embolus
EB	embolic base
L	lamella (= EP of Lopardo et al., in press)
PC	paracymbium
ST	subtegulum
T	tegulum
TM	tegular membrane

Epigynum:

CD	copulatory duct
CO	copulatory opening
FD	fertilization duct
S	spermatheca

Spinnerets and somatic morphology:

AC	aciniform gland spigot
AG	aggregate gland spigot
ALS	anterior lateral spinneret
CL	colulus
CY	cylindrical gland spigot
FL	flagelliform gland spigot
MAP	major ampullate gland spigot
mAP	minor ampullate gland spigot
N	nubbin
PI	piriform gland spigots
PLS	posterior lateral spinneret
PMS	posterior median spinneret
PS	pseudosegmentation
Tm	metatarsal trichobothrium
TR	tartipore

a few (3–4) piriform gland spigots (see also Lopardo et al. 2007); PLS with terminal segment nearly as long as basal, with one flagelliform gland spigot and one aggregate gland spigot, aciniform gland spigots absent (but see Discussion); female with one cylindrical gland spigot (Figs. 30, 34, 64, 66); PMS with a single spigot in *Africepheia* and *Synaphris* (Fig. 31; see Discussion), with two aciniform gland spigots in *Cepheia longiseta* (Lopardo and Hormiga, in press; Lopardo et al. 2007; see also Discussion); cylindrical gland spigot absent in female *Africepheia* and *Synaphris* (Figs. 31, 64), one present in *Cepheia longiseta* (Lopardo and Hormiga, in press; Lopardo et al. 2007).

Male palpal tibia with one dorsal trichobothrium; sometimes with small dorsal tibial process; no other apophyses on the male palpal tibia, patella, or femur (Figs. 22, 59, 74). Paracymbium present. Tegulum with membranous conductor grooved to receive embolus and terminating in one or two apophyses (Figs. 20, 58, 73; Lopardo and Hormiga, in press: fig. 46). Embolus filiform, moderately to very long, arises from the proximal part of the palp (Figs. 5, 39, 67).

Female palp complete, tarsal claw absent (Figs. 10, 43). Entelegyne, with one pair of spermathecae. Copulatory duct loops around itself or spermathecae at least one time (Figs. 7, 41, 69).

Circumscription.— *Africepheia* gen. nov., *Cepheia* Simon, 1894, *Synaphris* Simon, 1894. Wunderlich (1986) included the genus, *Iardinis* Simon, 1899 in his original circumscription of Synaphridae (which he considered a subfamily of a broadly circumscribed Anapidae). The type species of *Iardinis* is considered *nomen dubium* (Forster and Platnick 1977; Platnick 2007). However, Wunderlich's (1986) placement of *Iardinis* was based on his assessment of two species described from Nepal and India by Brignoli, not the type species. Wunderlich later added his new genus *Crassignatha* Wunderlich, 1995a (see also Wunderlich 1995b) and *Iardinidis* Wunderlich 2004, a fossil from Baltic amber, to Synaphridae. Marusik and Lehtinen (2003) suggested that *Crassignatha* might belong to Symphytognathidae; Wunderlich (2004) suggested Anapidae; Platnick (2007) has cataloged it under Mysmenidae. The placement of *Iardinidis* has not been critically evaluated.

Distribution.— Mediterranean Europe and Africa, Central Asia, Canary Islands, Madagascar.

Genus *Africepheia* Miller, gen. nov.

Type species: *Africepheia madagascariensis* Miller, sp. nov.

Etymology.— The generic name is a contraction of African *Cepheia*; the gender is feminine.

Diagnosis.— Male *Africepheia* distinguished from other synaphrids by the form of the paracymbium, which nearly covers the retrolateral face of the bulb and is lightly sclerotized and glabrous except along the ventral margin, which is more sclerotized and hirsute (Figs. 6, 18, 21), smaller and not less sclerotized than the adjacent cymbium in other synaphrids (Fig. 56); further distinguished from *Synaphris* by the conductor, which nearly covers the prolateral face of the cymbium and bulb (Fig. 17), smaller, not obscuring the cymbium in *Synaphris* (Fig. 55), and by the absence of both a lamella (see Fig. 57) and a glabrous, membranous, basal region on the prolateral side of the cymbium (see Fig. 70) in *Africepheia*; further distinguished from *Cepheia* by having the carapace longer than wide (Fig. 3), as long as wide in both sexes of *Cepheia* (Lopardo and Hormiga, in press: fig. 9), and by the form of the cymbium, which is several times longer than wide in *Cepheia* (Brignoli 1970: fig. 13; Thaler and Noflatscher 1990: figs. 25, 27; Lopardo and Hormiga, in press: figs. 46–49), only slightly longer than wide in *Africepheia* (Fig. 22).

Female distinguished from other synaphrids by the copulatory duct, which loops around itself about a dozen times in *Africepheia* (Fig. 7); no more than four loops in other synaphrids (Figs. 41, 69; Lopardo and Hormiga, in press: fig. 40), and by the anterolateral position of the copulatory openings in *Africepheia* (Figs. 23–24), ventral (Fig. 60; Lopardo and Hormiga, in press: fig. 57) or lateral (Fig. 78) in other synaphrids.

Circumscription.— *Africepheia madagascariensis* Miller, sp. nov.

Justification of Monotypy.— In the absence of a phylogenetic study, it is not clear how synaphrid genera are related and a thorough reexamination of symphytognathoid relationships is beyond the scope of this study. To avoid creation of a new monotypic genus, *Africepheia madagascariensis* could arguably be placed in *Cepheia* with a revised genus diagnosis based on the form of the conductor and its interaction with the embolus; no characters of the female are known that would diagnose such a circumscription. The weak and untested evidence for a sister taxon relationship between *Cepheia* and *Africepheia* combined with the few characters available to diagnose such a group argues against their synonymy. The case for placing *Africepheia* in *Synaphris* is even weaker. Although *Africepheia* and *Synaphris* share some features, including similarities in the form of the conductor apophyses, similar spinneret spigot morphologies, and (in some *Synaphris*) an epigynum in the form of a bulb rather than a flat plate, *Africepheia* lacks a lamella and a membranous basal region on the prolateral side of the cymbium, both key diagnostic characters and possible synapomorphies for *Synaphris* (Lopardo et al. 2007). It therefore seems preferable to establish a new monotypic genus rather than complicate the diagnoses of the existing genera.

***Africepheia madagascariensis* Miller, sp. nov.**

Figures 1–27, 29–34.

Material Examined.— Holotype: Male from Madagascar, **Antsiranana**: Réserve Spéciale de l'Ankarana, 22.9 km 224° SW Anivorano Nord, 12°54′32″S, 49°6′35″E, 80 m, 10–16 February 2001, EF19 sifted litter tropical dry forest, in tsingy, BLF 2972, Fisher, Griswold et al. (CASENT 9001446), deposited in CAS. Paratypes: Madagascar: **Antsiranana**: Réserve Spéciale de l'Ankarana, 22.9 km 224° SW Anivorano Nord, 12°54′32″S, 49°6′35″E, 80 m, 10–16 February 2001, EF19 sifted litter tropical dry forest, in tsingy, BLF 2972, Fisher, Griswold et al. (CASENT 9001446), 9♂, 20♀; Réserve Spéciale de l'Ankarana, 22.9 km 224° SW Anivorano Nord, Camp Anglaise, 12.90889°S, 49.10983°E, 80 m, 10–16 February 2001, general collecting, L.J. Boutin (CASENT 9003704), 1♂, 3♀.

Etymology.— Named for the island of Madagascar, where this species was discovered. The epithet is in the form of a Latin adjective.

Diagnosis.— Monotypic genus; see diagnosis for genus.

Description.— Carapace and sternum dark yellow to brown, paler specimens with darker margin, darker specimens nearly uniform color. Legs yellow to orange. Abdomen medium gray to black.

Male palp: Male palpal tibia with short distal process on the prolateral side (Fig. 22). Cymbium slightly longer than wide, distal margin rounded with arc of setae (Fig. 22). Paracymbium a large, glabrous, lightly sclerotized plate on the retrolateral side with a hirsute, moderately sclerotized ventral margin (Fig. 21). Tegulum with elaborate membranous conductor nearly covering the prolateral face of the palp and grooved to receive filiform embolus (Figs. 5, 19). Embolic tip and conductor apophyses with proximal orientation, located near origin of the very long, filiform embolus in unexpanded palp (Figs. 5, 20).

Epigynum: Ventral plate bulbous, with large anterolateral copulatory openings (Figs. 23–24). Copulatory duct loops around itself about a dozen times (Fig. 7). Spermathecae separated by more than two times their diameter.

Male (holotype): Total length 0.99, carapace 0.48 long, 0.40 wide, clypeus 0.17, sternum 0.29 long, 0.29 wide, coxa IV separated by 1.50 times their width. Leg measurements:

	I	II	III	IV	Palp
Femur	0.49	0.45	0.38	0.43	0.13
Patella	0.13	0.12	0.12	0.13	0.05
Tibia	0.45	0.38	0.31	0.39	0.15
Metatarsus	0.31	0.28	0.26	0.29	–
[Tm position	0.47	0.46][1]	–	–	–
Tarsus	0.27	0.27	0.24	0.24	0.27
Total	**1.65**	**1.50**	**1.31**	**1.48**	**0.60**

Female (paratype, CASENT 9001446): Total length 1.11, carapace 0.41 long, 0.36 wide, clypeus 0.12, sternum 0.26 long, 0.28 wide, coxa IV separated by 2.00 times their width. Leg measurements:

	I	II	III	IV	Palp
Femur	0.41	0.39	0.35	0.42	0.07
Patella	0.13	0.13	0.12	0.11	0.03
Tibia	0.33	0.30	0.26	0.33	0.09
Metatarsus	0.26	0.24	0.22	0.25	–
[Tm position	0.49	0.42]	–	–	–
Tarsus	0.25	0.22	0.21	0.21	0.09
Total	**1.38**	**1.28**	**1.16**	**1.32**	**0.28**

Variation.— *Male* (4): Total length 0.99–1.06 (1.03), carapace length 0.43–0.48 (0.45), carapace width 0.38–0.40 (0.39), clypeus height 0.14–0.17 (0.16), sternum length 0.26–0.29 (0.28), sternum width 0.29–0.30 (0.29), coxa IV separated by 1.50–1.93 (1.72) times their width.

Female (4): Total length 0.97–1.11 (1.05), carapace length 0.40–0.41 (0.40), carapace width 0.36–0.37 (0.36), clypeus height 0.10–0.12 (0.11), sternum length 0.26–0.28 (0.27), sternum width 0.25–0.28 (0.27), coxa IV separated by 1.57–2.00 (1.74) times their width.

Distribution.— Known from Antsiranana province, northern Madagascar (Fig. 80).

Genus *Synaphris* Simon, 1894

Synaphris Simon 1894:589. Type species by monotypy and original designation *Grammonota letourneuxi* (Simon 1884). Levi and Levi 1962:29. Wunderlich 1980: 260; 2004:1083. Marusik and Lehtinen 2003: 148. Lopardo, Hormiga and Melic 2007:15.

Diagnosis.— Male *Synaphris* distinguished from those of *Cepheia* and *Africepheia* by the conductor, which does not obscure the cymbium in prolateral view (Fig. 55) as it does in *Cepheia* (Lopardo and Hormiga, in press: fig. 42) and *Africephia* (Fig. 17), and by the presence of both a lamella (Fig. 57) and a glabrous, membranous, basal region on the prolateral side of the cymbium (Fig. 70), both absent in *Cepheia* and *Africepheia*.

Female distinguished from *Africepheia* by having no more than 4 coils of the copulatory duct around itself (Figs. 41, 69), about a dozen in *Africepheia* (Fig. 7); from *Cepheia* by the copulatory duct, which loops around itself in *Synaphris* (Fig. 69), around the spermathecae in *Cepheia* (Lopardo and Hormiga, in press: fig. 40), and by having the carapace longer than wide (Fig. 37), as long as wide in both sexes of *Cepheia* (Lopardo and Hormiga, in press: fig. 3).

Description.— Male palpal tibia with nearly straight distal margin (Figs. 59, 74). Cymbium with retrolateral paracymbium (Figs. 40, 56, 68, 71), with a glabrous, membranous, basal region on the prolateral side (Figs. 55, 70). A membranous lamella arises from the embolus base (Figs. 57, 72; possibly absent in species from the Comoros, see Marusik and Lehtinen 2003); conductor with a

[1] In the measurement tables that follow, Tm position refers to the position of the metatarsal trichobothrium (see Methods, p. 22). Its values are not included in the column totals.

groove that receives the embolus on the prolateral side (Figs. 55, 70), sometimes extending around the front of the bulb onto the retrolateral side (Marusik et al. 2005: fig. 8); conductor with a subterminal apophysis near the distal part of the bulb (Figs. 58, 73).

Circumscription.— *Synaphris agaetensis* Wunderlich, 1987, *S. calerensis* Wunderlich, 1987, *S. dalmatensis* Wunderlich, 1980, *S. franzi* Wunderlich, 1987, *S. lehtineni* Marusik, Gnelitsa and Kovblyuk, 2005, *S. letourneuxi* (Simon, 1884; type species), *S. orientalis* Marusik and Lehtinen, 2003, *S. schlingeri* Miller, sp. nov, *S. saphrynis* Lopardo, Hormiga and Melic, 2007, *S. toliara* Miller, sp. nov.

Distribution.— Mediterranean Europe and Africa, Central Asia, Canary Islands, Madagascar.

***Synaphris schlingeri* Miller, sp. nov.**

Figures 28, 35–52, 55–66

Material Examined.— Holotype: Male from Madagascar, **Toliara**, Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77° ENE Efoetse, 17.4 km 170° S Beheloka, 24°2′50″S, 43°45′11″E, 40 m, 18–22 March 2002, spiny forest/thicket, EH18 pitfall trap, BLF 6161, B.L. Fisher (CASENT 9000566), deposited in CAS. Paratype: Madagascar: **Antsiranana:** Forêt d'Orangea, 3.6 km 128° SE Remena 12°15′32″S, 49°22′29″E, 90 m, 22–28 February 2001, littoral rainforest, EG21 pitfall trap, BLF3127, Fisher, Griswold et al. (CASENT 9007105) 1♂. *Toliara:* Forêt de Tsinjoriaky, 6.2 km 84° E Tsifota, 22°48′8″S, 43°25′14″E, 70 m, 6–10 March 2002, spiny forest/thicket, EH11 sifted litter (leaf mold, rotten wood), BLF 5966, B.L. Fisher et al. (CASENT 9012956), 1♂; [same locality] (CASENT 9014413) 1♀; Mahafaly Plateau, 6.2 km 74° ENE Itampolo, 24°39′13″S, 43°59′48″E, 80 m, 21–25 February 2002, spiny forest/thicket, EH18 pitfall trap, BLF 5758, B.L. Fisher et al. (CASENT 9013288), 1♀; Réserve Spéciale de Cap Sainte Marie, 12.3 km 262° W Marovato, 25°34′54″S, 45°10′6″E, 200 m, 11–15 February 2002, spiny forest/thicket, EH11 sifted litter (leaf mold, rotten wood), BLF 5500, B.L. Fisher et al. (CASENT 9000318), 1♀.

Etymology.— Epithet a patronymic in honor of Evert Schlinger, whose foundation supported this research and has contributed greatly to arachnological and entomological research, especially in Madagascar.

Diagnosis.— Male of *S. schlingeri* and *S. toliara* distinguished from *S. agaetensis* and *S. calerensis* (Canary Islands) by the presence of a grooved conductor that accommodates the embolus (Figs. 55, 70; Marusik and Lehtinen 2003); from *S. orientalis* (Turkmenistan), *S. lehtineni* (Ukraine), *S. dalmatensis* (Croatia), and *S. letourneuxi* (Egypt) by the much shorter embolus and at least from *S. orientalis* and *S. lehtineni* by the lack of a cymbial groove that conducts the embolus (Fig. 55; unknown for *S. dalmatensis* and *S. letourneuxi*) and the form of the lamella, which is much narrower at its base than at its widest point in *S. orientalis* (Marusik et al. 2005: fig. 15) and *S. lehtineni* (Marusik et al. 2005: fig. 7), nearly as wide at the base as the widest point in *S. schlingeri* (Fig. 57) and *S. toliara* (Fig. 72). Male of *S. schlingeri* distinguished from *S. toliara* by the much smaller cheliceral keel (Fig. 48) than either the female of *S. schlingeri* (Fig. 49) or either sex of *S. toliara* (Figs. 53–54), by having more strongly developed TA and SA in *S. toliara* (Fig. 73), and by the form of the embolus, which is shorter and continuous with the embolic base in *S. schlingeri* (Fig. 55), longer with a clearly defined base in *S. toliara* (Fig. 70). Also, *S. toliara* have a tegular membrane with a fringed tip running parallel to the lamella (Figs. 72–73); this appears to be unique among synaphrids.

Female of *S. schlingeri* distinguished from *S. agaetensis*, *S. calerensis*, and *S. franzi* (Canary Islands) by the lack of an oval depression in the epigynal area (Marusik and Lehtinen 2003); from *S. lehtineni* by the much narrower, loosely coiled copulatory ducts (Fig. 41); from *S. toliara* by the larger spermathecae separated by less than their diameter (Fig. 28), 4× coil of the copulatory duct around itself (Fig. 41; 2× in *S. toliara*), ventral copulatory openings and lack of a Y-shaped plate in *S. schlingeri* (Fig. 60; lateral copulatory openings at the base of a Y-shaped plate in *S. toliara*).

Description.— Carapace brown. Sternum brown. Chelicerae dusky yellow to brown, keel on anterior margin relatively small. Legs yellow to brown. Abdomen medium to dark gray with four round dorsal sigilla.

Male palp: Cymbium without a groove that guides the embolus (compare Fig. 55 with fig. 6 in Marusik et al. 2005). Conductor with deep groove (compare Fig. 55 with fig. 11 in Marusik et al. 2005). Embolus continuous with the base (Fig. 55). Lamella with a wide base (Fig. 57).

Epigynum: Ventral plate flat with ventral copulatory openings (Fig. 60). Copulatory duct loops around itself four times (Fig. 41). Ducts narrow, loosely coiled. Spermathecae separated by less than half their diameter (Fig. 28).

Male (holotype): Total length 0.85, carapace 0.41 long, 0.35 wide, clypeus 0.07, sternum 0.29 long, 0.25 wide, coxa IV separated by 1.64 times their width. Leg measurements:

	I	II	III	IV	Palp
Femur	0.33	0.31	0.26	0.33	0.09
Patella	0.11	0.11	0.10	0.11	0.04
Tibia	0.26	0.24	0.20	0.27	0.06
Metatarsus	0.19	0.18	0.17	0.19	–
[Tm position	0.46	0.44]	–	–	–
Tarsus	0.21	0.21	0.19	0.19	0.09
Total	**1.10**	**1.05**	**0.92**	**1.09**	**0.28**

Female (paratype): Total length 0.92, carapace 0.36 long, 0.31 wide, clypeus 0.07, sternum 0.23 long, 0.22 wide, coxa IV separated by 1.54 times their width. Leg measurements:

	I	II	III	IV	Palp
Femur	0.28	0.28	0.23	0.30	0.08
Patella	0.10	0.10	0.09	0.09	0.03
Tibia	0.20	0.19	0.15	0.23	0.05
Metatarsus	0.16	0.15	0.14	0.17	–
[Tm position	0.45	0.48]	–	–	–
Tarsus	0.18	0.18	0.17	0.18	0.06
Total	**0.92**	**0.90**	**0.78**	**0.97**	**0.22**

Variation.— *Male* (4): Total length 0.73–0.85 (0.78), carapace length 0.37–0.41 (0.38), carapace width 0.30–0.35 (0.33), clypeus height 0.04–0.07 (0.06), sternum length 0.23–0.29 (0.25), sternum width 0.21–0.25 (0.23), coxa IV separated by 1.50–1.92 (1.64) times their width.

Female (4): Total length 0.71–0.92 (0.85), carapace length 0.36–0.37 (0.36), carapace width 0.31–0.34 (0.32), clypeus height 0.04–0.07 (0.06), sternum length 0.23–0.24 (0.23), sternum width 0.22–0.23 (0.23), coxa IV separated by 1.50–1.69 (1.54) times their width.

Distribution.— Known from coastal parts of Antsiranana province in the north and Toliara province in the south of Madagascar (Fig. 80). Presumably, this species can also be found in intervening parts of Madagascar. *Synaphris schlingeri* and *S. toliara* are syntopic at least in southern Madagascar, but *S. toliara* is much more abundant in collections.

Synaphris toliara Miller, sp. nov.

Figures 53–54, 67–79.

Material Examined.— Holotype: Male from Madagascar, **Toliara**, Forêt de Tsinjoriaky, 6.2 km 84° E Tsifota, 22°48′8″S, 43°25′14″E, 6–10 March 2002, 70 m, spiny forest/thicket, EH11 sifted litter (leaf mold, rotten wood), BLF5966, B.L. Fisher, et al. (CASENT 9012956), deposited in CAS. Paratypes: Madagascar: **Toliara**: Forêt de Beroboka, 5.9 km 131° SE Ankidranoka, 22°13′59″S, 43°21′59″E, 80 m, 12–16 March 2002, tropical dry forest, EF19 sifted litter (leaf mold, rotten wood), BLF 6070, B.L. Fisher et

al. (CASENT 9000643), 1♂, 1♀; [same locality] (CASENT 9000645), 1♀; Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota, 22°48′8″S, 43°25′14″E, 70 m, 6–10 March 2002, spiny forest/thicket, EH11 sifted litter (leaf mold, rotten wood), BLF 5966, B.L. Fisher et al. (CASENT 9012956), 8♂, 11♀; Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77° ENE Efoetse, 17.4 km 170° S Beheloka, 24°2′50″S, 43°45′11″E, 40 m, 18–22 March 2002, spiny forest/thicket, EH18 pitfall trap, BLF 6161, B.L. Fisher (CASENT 9000566), 1♀; Mahafaly Plateau, 6.2 km 74° ENE Itampolo, 24°39′13″S, 43°59′48″E, 80 m, 21–25 February 2002, spiny forest/thicket, EH18 pitfall trap, BLF 5763, B.L. Fisher et al. (CASENT 9014273), 1♂; Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km ENE Amboasary, 7.6 km 99° E Hazofotsy, 24°49′1″S, 46°36′36″E, 150 m, 12–16 January 2002, spiny forest/thicket, EH11 sifted litter (leaf mold, rotten wood), BLF 4810, B.L. Fisher et al. (CASENT 9012035), 1♂; Réserve Spéciale de Cap Sainte Marie, 12.3 km 262° W Marovato, 25°34′54″S, 45°10′6″E, 200 m, 11–15 February 2002, spiny forest/thicket, EH11 sifted litter (leaf mold, rotten wood), BLF 5500, B.L. Fisher et al. (CASENT 9000318), 5♂, 11♀.

Etymology.— Named for the province in Madagascar from which all known specimens of this species were collected. The epithet a noun in apposition.

Diagnosis.— For male, see diagnosis of *S. schlingeri*.

Female of *S. toliara* distinguished from *S. agaetensis*, *S. calerensis*, and *S. franzi* Wunderlich, 1987 (Canary Islands) by the lack of an oval depression in the epigynal area (Marusik and Lehtinen 2003); from *S. lehtineni* and *S. schlingeri* by having a 2× coil of the copulatory duct around itself (Fig. 69; 3–4× in *S. lehtineni* and *S. schlingeri*); further distinguished from *S. schlingeri* by having smaller spermathecae separated by more than their diameter (Fig. 79), and by the presence of a Y-shaped plate with the copulatory openings at the base (Figs. 77–78).

Synaphris toliara is the smallest synaphrid (carapace length 0.31–0.33); only *S. schlingeri* (carapace length 0.36–0.41) and *S. agaetensis* (carapace length 0.38) have a carapace length less than 0.4.

Description.— Carapace dark yellow with darker margin. Sternum dark yellow to brown, chelicerae dark yellow. Legs dark yellow. Abdomen dark gray to black with four round dorsal sigilla.

Male palp: Cymbium without a groove that guides the embolus (compare Fig. 70 with fig. 6 in Marusik et al. 2005). Conductor with deep groove (compare Fig. 70 with fig. 11 in Marusik et al. 2005). Embolus narrow with bulbus base (Figs. 67, 70). Lamella with a wide base (Fig. 72). Tegular membrane with terminal fringe runs parallel to lamella (Figs. 72–73). Apophysis near tip of conductor strong (Figs. 68, 73).

Epigynum: Ventral plate with a pair of ventrolaterally projecting keels, lateral copulatory openings (Figs. 77–78). Copulatory duct loops around itself two times (Fig. 69). Ducts thick, loosely coiled. Spermathecae separated by about their diameter (Fig. 79).

Male (holotype): Total length 0.63, carapace 0.31 long, 0.30 wide, clypeus 0.07, sternum 0.22 long, 0.22 wide, coxa IV separated by 1.33 times their width. Leg measurements:

	I	II	III	IV	Palp
Femur	0.33	0.30	0.26	0.33	0.09
Patella	0.11	0.11	0.09	0.09	0.04
Tibia	0.25	0.24	0.20	0.26	0.07
Metatarsus	0.20	0.20	0.17	0.20	–
[Tm position	0.43	0.44]	–	–	–
Tarsus	0.22	0.22	0.19	0.21	0.12
Total	**1.11**	**1.07**	**0.91**	**1.09**	**0.32**

Female (paratype, CASENT 9012956): Total length 0.81, carapace 0.33 long, 0.31 wide, clypeus 0.08, sternum 0.24 long, 0.23 wide, coxa IV separated by 1.69 times their width. Leg measurements:

	I	II	III	IV	Palp
Femur	0.33	0.30	0.27	0.33	0.06
Patella	0.10	0.11	0.11	0.11	0.03
Tibia	0.25	0.24	0.20	0.26	0.06
Metatarsus	0.20	0.19	0.18	0.19	–
[Tm position	0.49	0.40]	–	–	–
Tarsus	0.22	0.21	0.19	0.19	0.07
Total	**1.10**	**1.05**	**0.95**	**1.08**	**0.22**

Variation.— *Male* (4): Total length 0.63–0.67 (0.66), carapace length 0.31–0.32 (0.31), carapace width 0.29–0.30 (0.29), clypeus height 0.07–0.09 (0.08), sternum length 0.22–0.23 (0.22), sternum width 0.19–0.22 (0.21), coxa IV separated by 1.33–1.58 (1.45) times their width.

Female (4): Total length 0.68–0.81 (0.72), carapace length 0.31–0.33 (0.32), carapace width 0.30–0.33 (0.31), clypeus height 0.07–0.08 (0.08), sternum length 0.23–0.24 (0.24), sternum width 0.22–0.23 (0.23), coxa IV separated by 1.36–1.75 (1.62) times their width.

Distribution.— Known from the southern coast of Madagascar, Toliara province (Fig. 80).

Discussion

Anatomy and Synapomorphy.— Recent anatomical work on *Synaphris*, based largely on scanning electron microscopy, has been impressive (Lopardo et al. 2007; Marusik et al. 2005; Marusik and Lehtinen 2003), providing a solid basis for comparing these tiny, obscure spiders to their relatives. Until recently (Lopardo and Hormiga, in press), the same could not be said for *Cepheia*. Schütt (2003) included *Cepheia* in her cladistic analysis of higher symphytognathoid spiders. Although some important observations were documented in the data matrix, precious few images were published.

The form of the tibial bothrium was proposed as a putative synapomorphy for Synaphridae based on scanning electron microscopy of a central Asian *Synaphris* species (Marusik and Lehtinen 2003). This bothrium has a deep central notch and small pit (Marusik and Lehtinen 2003: fig. 23). However, no synaphrid subsequently studied using scanning electron microscopy has been found to exhibit such a bothrium (Figs. 15, 51; Lopardo and Hormiga, in press; Lopardo et al. 2007; Marusik et al. 2005). Clearly, the bothrium form discussed in Marusik and Lehtinen (2003) is not a synapomorphy for Synaphridae or even universal within *Synaphris*. The typical bothrium form in Synaphridae is hooded, a characteristic shared at least with Anapidae (Platnick and Forster 1989: fig. 15), Micropholcommatidae (Forster and Platnick 1984: figs. 374–375), Mysmenidae (Griswold 1985: fig. 8), Theridiosomatidae (unpublished data), Malkaridae (Platnick and Forster 1987: fig. 18), Linyphiidae (Hormiga 2002: fig. 46G), Synotaxidae (Forster et al. 1990: figs. 144, 260), and many non-araneoid spider families (Forster and Platnick 1984; Griswold et al. 2005); bothria in other araneoid families including araneids (Griswold et al. 1998: fig. 22E), theridiids (Agnarsson 2004: figs. 31G, 69E, 74D), cyatholipids (Griswold 2001: fig. 6B), and mimetids (Griswold et al. 2005: fig. 149G) are evenly rounded and lack a hood.

Marusik et al. (2005) showed that the tarsi of a central Asian *Synaphris* species are divided into two pseudosegments. They suggested that this could be synapomorphic for Synaphridae. Malagasy *Synaphris* and *Africepheia* also have pseudosegmented tarsi (Fig. 13). However, this feature is not universal among synaphrids (Lopardo and Hormiga, in press; Lopardo et al. 2007).

Marusik and Lehtinen (2003) mentioned (but provided no figures of) a prominent subdistal lyriform organ on the metatarsus, noting that it is unique among the higher araneoids. However, such an organ is actually found in several araneoid families (Lopardo et al. 2007). Lopardo et al.

(2007) suggest that the contraction at the metatarsus-tibia joint could be synapomorphic for the family. The presence of such a contraction in Malagasy *Synaphris* and *Africepheia* corroborates the hypothesis that this feature is synapomorphic for the family (Fig. 12).

The conformation of the cheliceral dentation, only one large keel on the anterior margin (Figs. 11, 47–49, 53–54), is a useful character for diagnosing Synaphridae (Wunderlich 1995a). Anapids, micropholcommatids, symphytognathids, mysmenids, theridiosomatids, cyatholipids, and synotaxids (among others) all have more teeth (Forster et al. 1990; Griswold et al. 1998; Griswold 2001; Schütt 2003). The enigmatic six-eyed genera *Iardinis* and *Crassignatha* may have synaphrid-type cheliceral dentation (Brignoli 1978: fig. 6; Wunderlich 1995b: fig. 16).

The labral spur was considered a synapomorphy of Anapidae until it was discovered in Micropholcommatidae (Schütt 2000: fig. 5D–F, 2003; but see Platnick and Forster 1986). Schütt (2003) coded *Cepheia* as lacking the labral spur (Fig. 46); *Africepheia* and *Synaphris* (Fig. 46; Lopardo et al. 2007: fig. 5) also lack the spur.

Male and female *Synaphris* appear to have a small pore plate on the prosoma above the endite. The sulcus is shallow and has a single pore (Figs. 42, 45); no such structure was seen in *Africepheia*. Similar (often more elaborate) structures are known in some anapids and micropholcommatids (Platnick and Forster 1986, 1989; Schütt 2003).

Spinneret Spigot Morphology.— Male and female synaphrids have one aggregate gland spigot and one flagelliform gland spigot on the PLS (Figs. 30, 34, 64, 66). A triplet of two aggregate gland spigots plus a flagelliform gland spigot on the PLS is a key synapomorphy of araneoid spiders (Coddington 1986; Griswold et al. 1998) although reductions and losses are not uncommon (Agnarsson 2004; Miller and Hormiga 2004). The loss of one aggregate gland spigot appears to be synapomorphic for Synaphridae. In most araneoids, the triplet is lost or vestigial in adult males, although it remains functional in some groups including cyatholipids (Griswold 2001), some linyphiids (Miller and Hormiga 2004), and the symphytognathoid families (Griswold et al. 1998; Schütt 2003).

Synaphrids have only one cylindrical gland spigot located on the PLS of females (Figs. 30, 64), a character state shared with cyatholipids and many synotaxids; other araneoids typically have two on the PLS (Griswold et al. 1998). Lopardo et al. (2007) note several other similarities between cyatholipids and synaphrids that may be phylogenetically significant. This contradicts Schütt's (2003) cladistic hypothesis that synaphrids belong among the symphytognathoid families; cyatholipids were not included in Schütt's study.

Cepheia longiseta is the only synaphrid with a cylindrical gland spigot on the PMS (Lopardo and Hormiga, in press; Lopardo et al. 2007). Two other enigmatic objects, one on the PMS and one on the PLS of *Cepheia longiseta*, were identified by Lopardo and collaborators (Lopardo and Hormiga, in press; Lopardo et al. 2007) as chemosensory setae, not spigots. To my knowledge, chemosensory setae have not been previously identified on spider spinnerets. Schütt (2003) identified the questionable object on the PMS as a minor ampullate gland spigot, even though the object is located on the anterior median part of the spinneret rather than the posterior part as is typical for this spigot (Coddington 1989). The questionable object on the PLS could alternatively be interpreted as an aciniform gland spigot.

Males and females of *Synaphris* and *Africepheia* have only one spigot on the PMS. This is tentatively identified as a minor ampullate gland spigot based on its relatively large size and the observation that the number of aciniform gland spigots is often homoplasious, whereas changes in the number of ampullate gland spigots are rare in araneoid evolution (Griswold et al. 1998; Miller and Hormiga 2004). However, if *Cepheia longiseta* has aciniform gland spigots and no minor ampullate gland spigot (Lopardo and Hormiga, in press; Lopardo et al. 2007), perhaps the spigot in

Synaphris and *Africepheia* is actually an aciniform gland spigot. This would imply that the loss of the minor ampullate gland spigot is synapomorphic for the family and is more parsimonious than independent losses of one kind of spigot in *Cepheia* and another kind in the other synaphrid genera.

Araneoid spiders typically have the spinning field of the ALS divided into two distinct sections, the piriform gland spigot region and the major ampullate gland spigot region (e.g., Griswold et al. 1998: fig. 28B). The reduction or loss of this separation is a putative synapomorphy for Synaphridae (Fig. 32; Lopardo et al. 2007; Schütt 2003).

Conclusion

A sustained, large scale effort to inventory arthropods in Madagascar has provided a wealth of raw material facilitating new discoveries about the fauna of this biodiversity hotspot (Fisher 2005). Nearly all of the specimens studied for this research were collected by Fisher and collaborators as part of his inventory initiative. The detection of synaphrids in Madagascar represents a major range extension for the family. Until recently, synaphrids were an obscure group with few useful illustrations or descriptions. Now, Synaphrids are enjoying a great deal of attention from morphologists (Lopardo and Hormiga, in press; Lopardo et al. 2007; Marusik et al. 2005; Marusik and Lehtinen 2003). As arachnologists become more familiar with synaphrids, it becomes much more likely that they will be discovered in other parts of the world.

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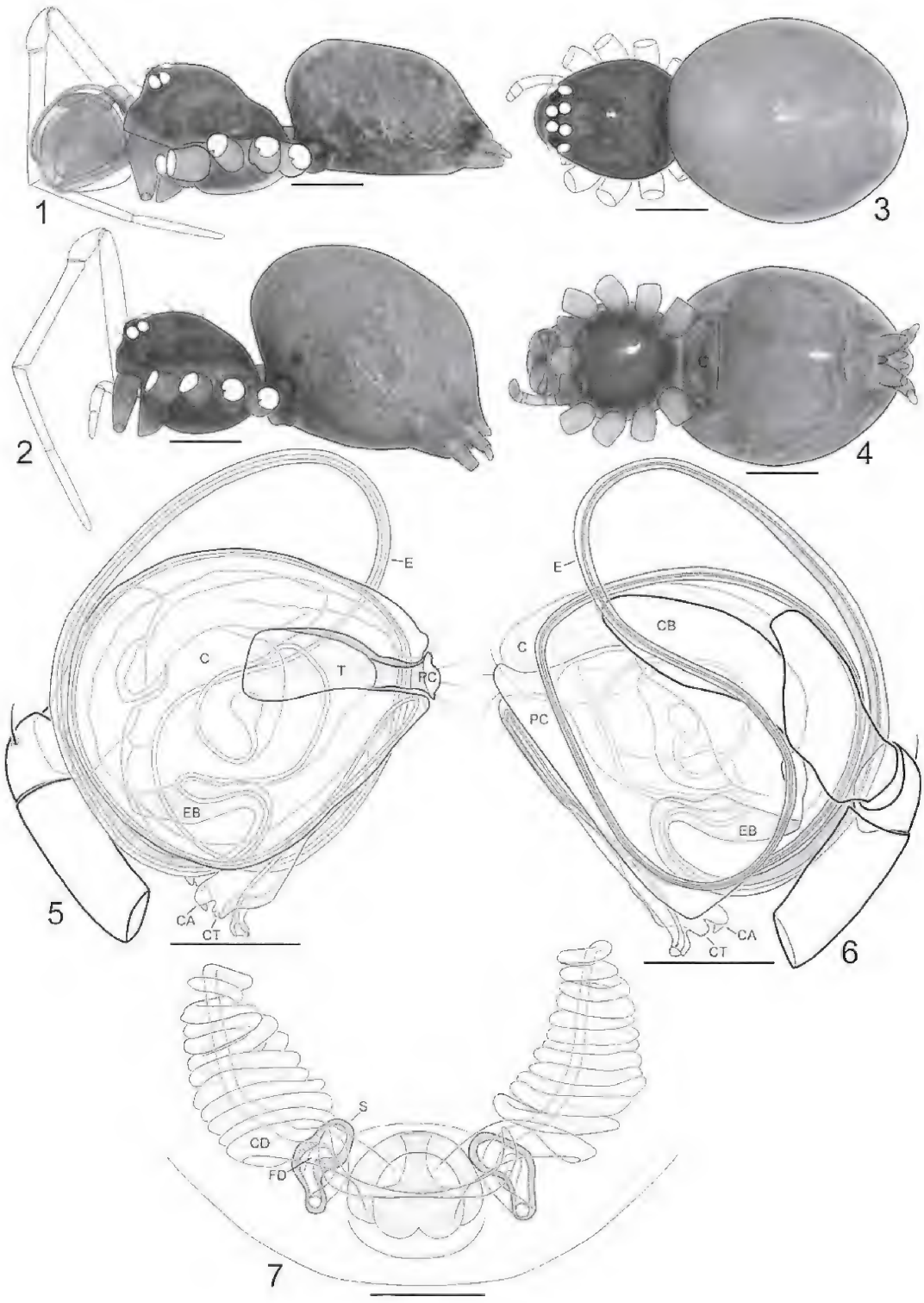
Figures 1–7 (right). *Africepheia madagascariensis*. 1, 5–6, male; 2–4, 7–8, female. 1–2. Habitus, lateral. 3. Habitus, dorsal. 4. Habitus, ventral. 5–6. Palp. 5. Prolateral. 6. Retrolateral. 7. Cleared epigynum, dorsal. Scale bars: 1–4 = 0.2 mm; 5–6 = 0.1 mm; 7 = 0.05 mm. For abbreviations see Table 1 (p. 22).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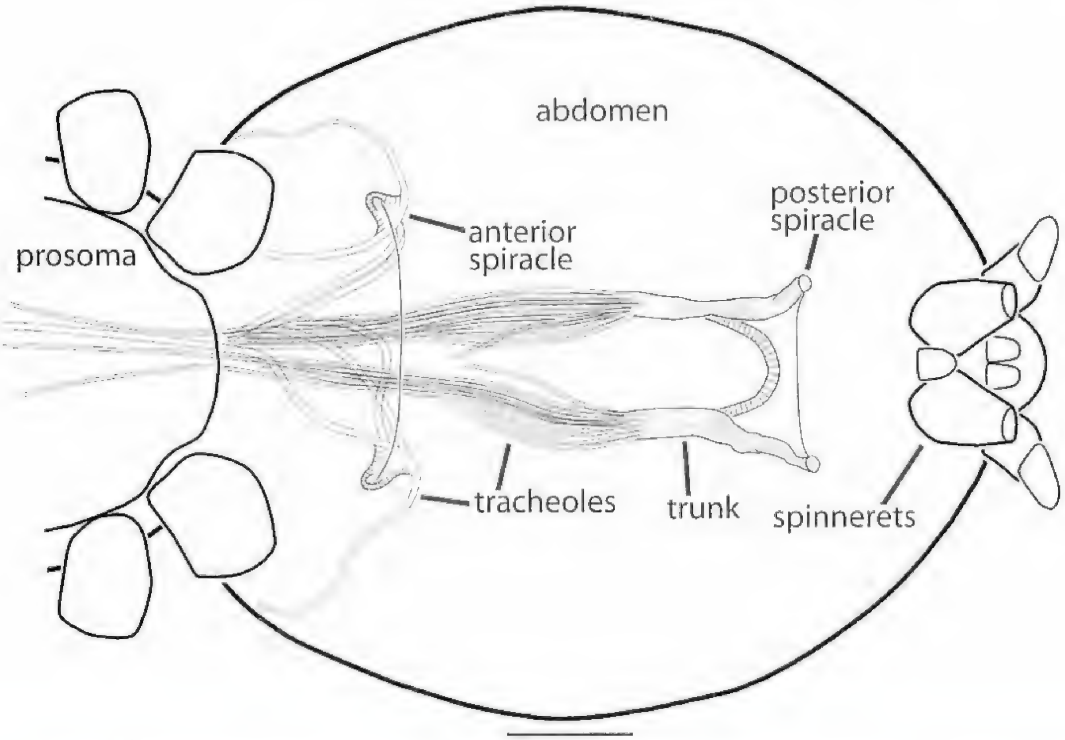
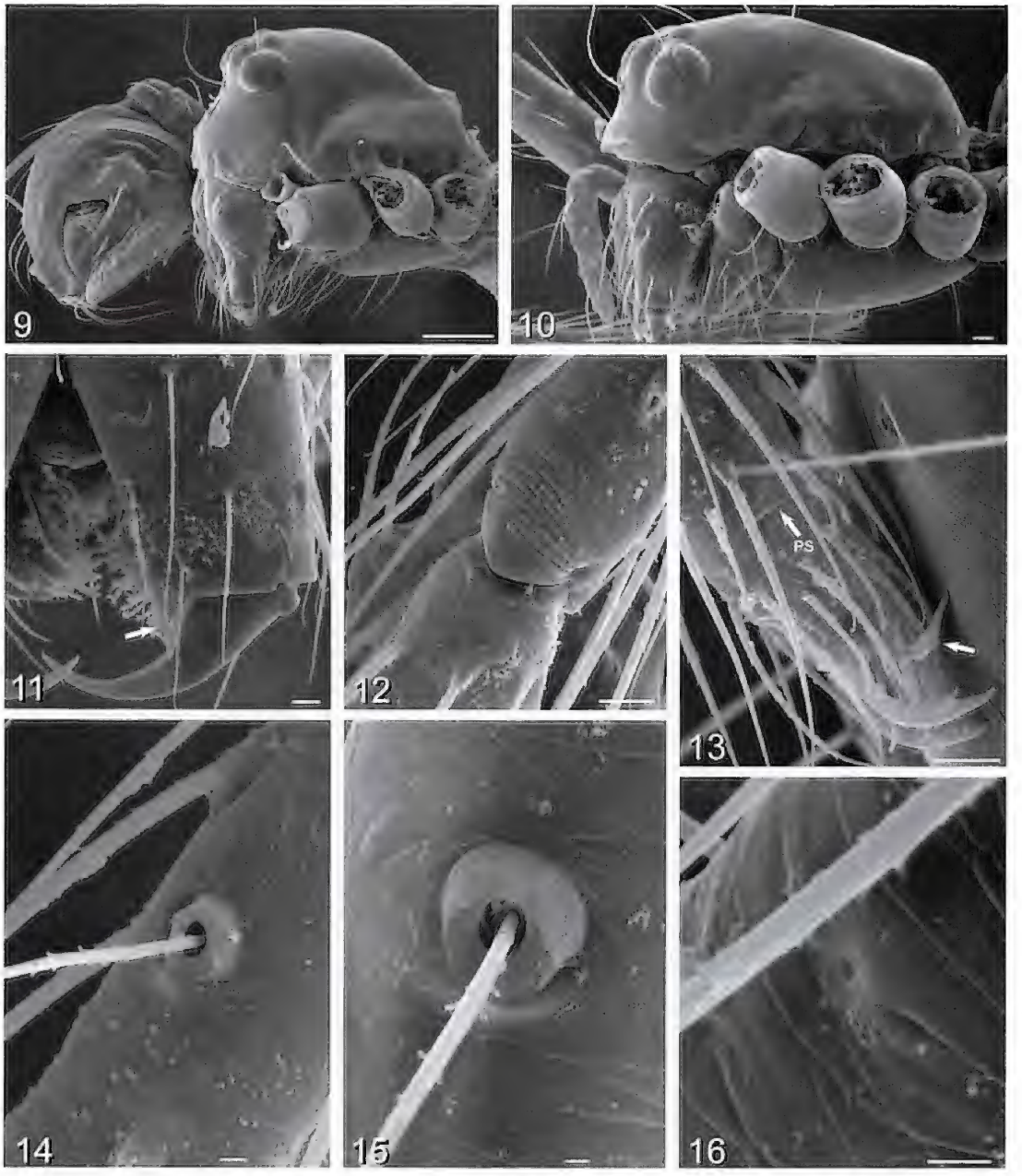
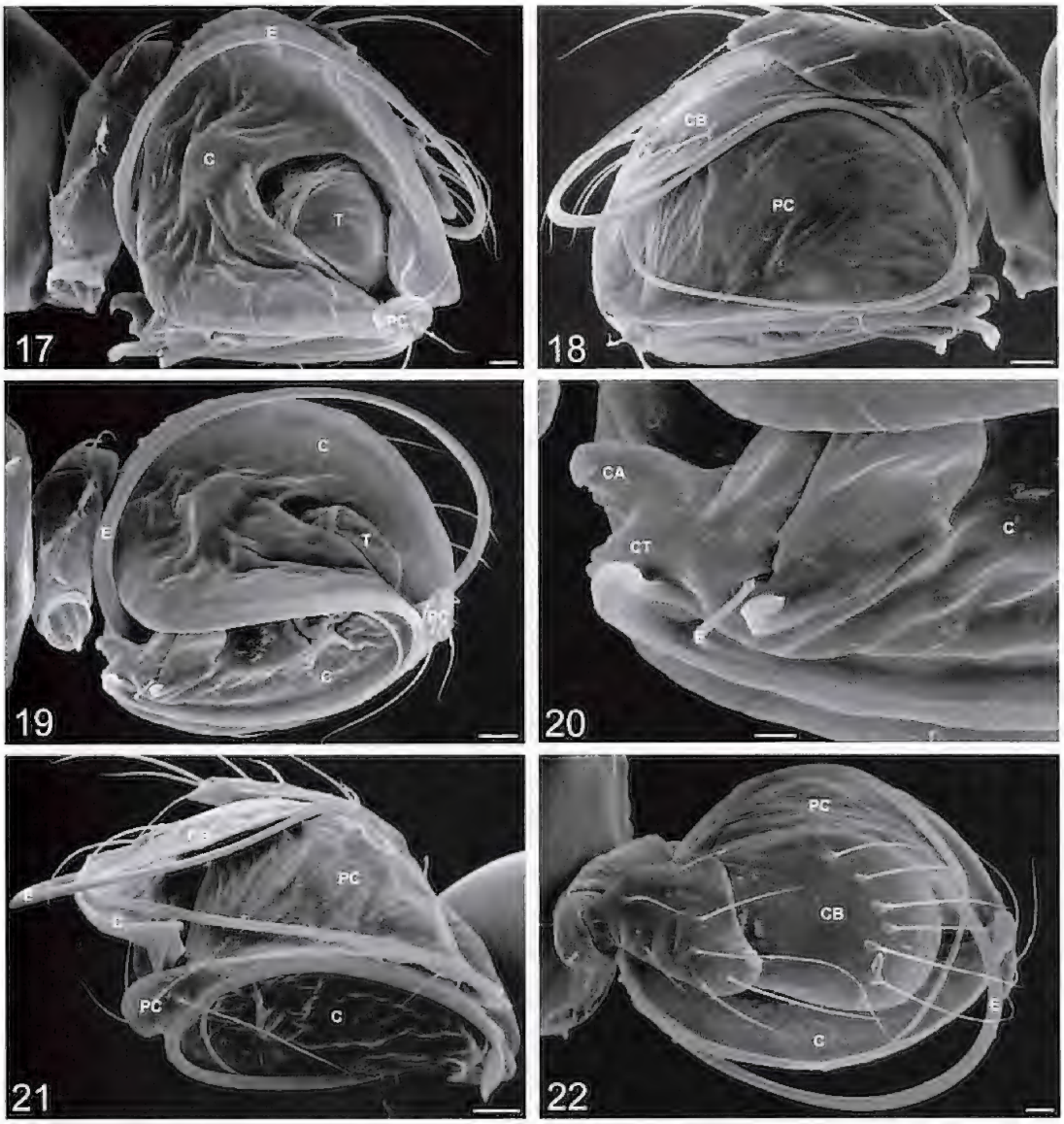


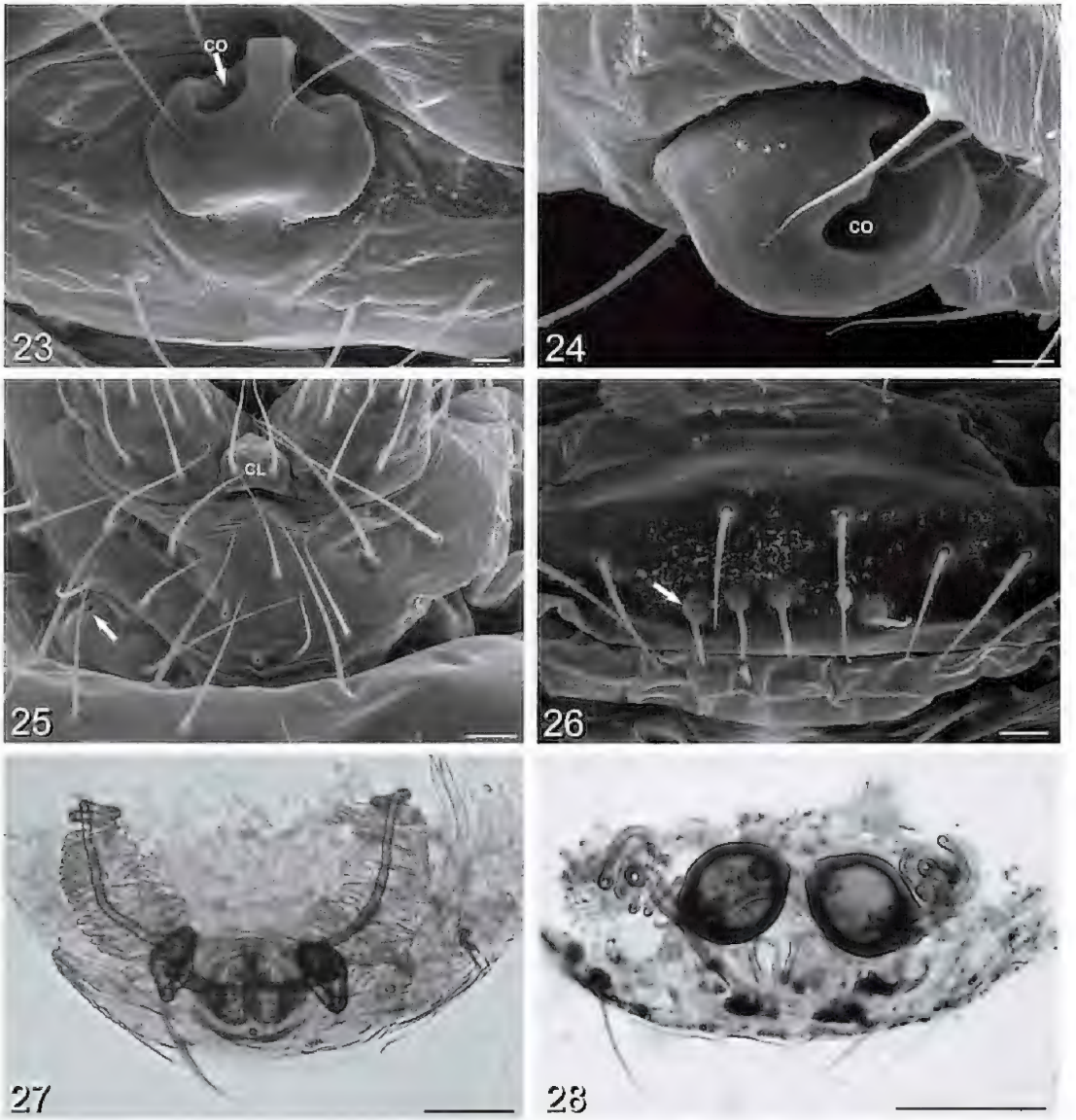
FIGURE 8. *Africepheia madagascariensis*. Cleared female showing respiratory system, ventral view. Scale bar = 0.01 mm.



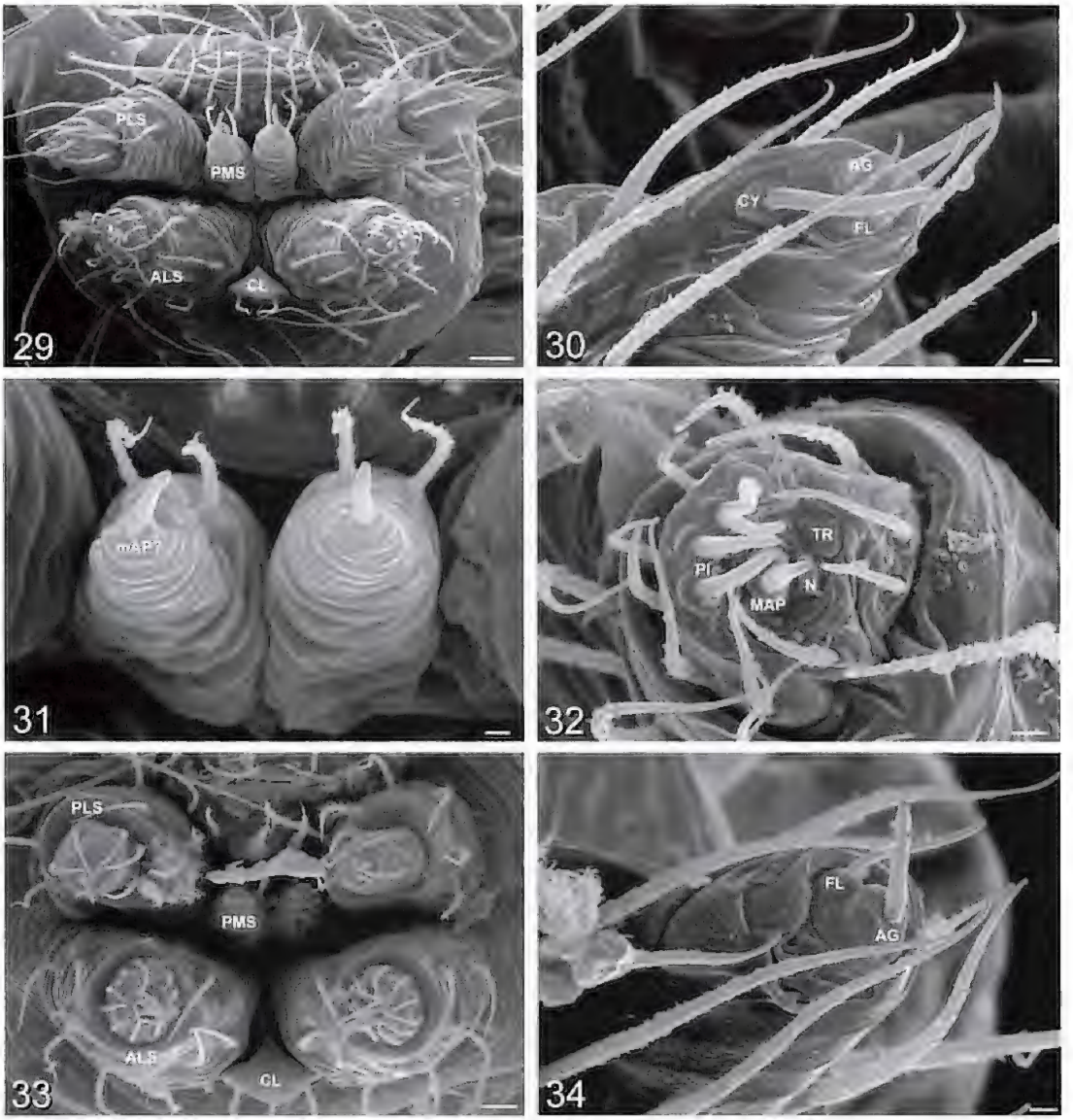
FIGURES 9–16. *Africepheia madagascariensis*. 9, male; 10–16, female. 9–10, Prosoma, lateral. 11. Chelicera, anterior, arrow indicates keel. 12. Junction of metatarsus and tibia I, note tapered tip of metatarsus and transverse ridges. 13. Tarsus I, note pseudosegmentation, unlabelled arrow indicates dorsal denticle on inferior claw. 14. Trichobothrium on metatarsus I. 15. Trichobothrium on tibia I. 16. Tarsal organ. Scale bars: 9 = 100 µm; 10 = 20 µm; 11–13 = 10 µm; 14, 16 = 3 µm; 15 = 2 µm. For abbreviations see Table 1 (p. 22).



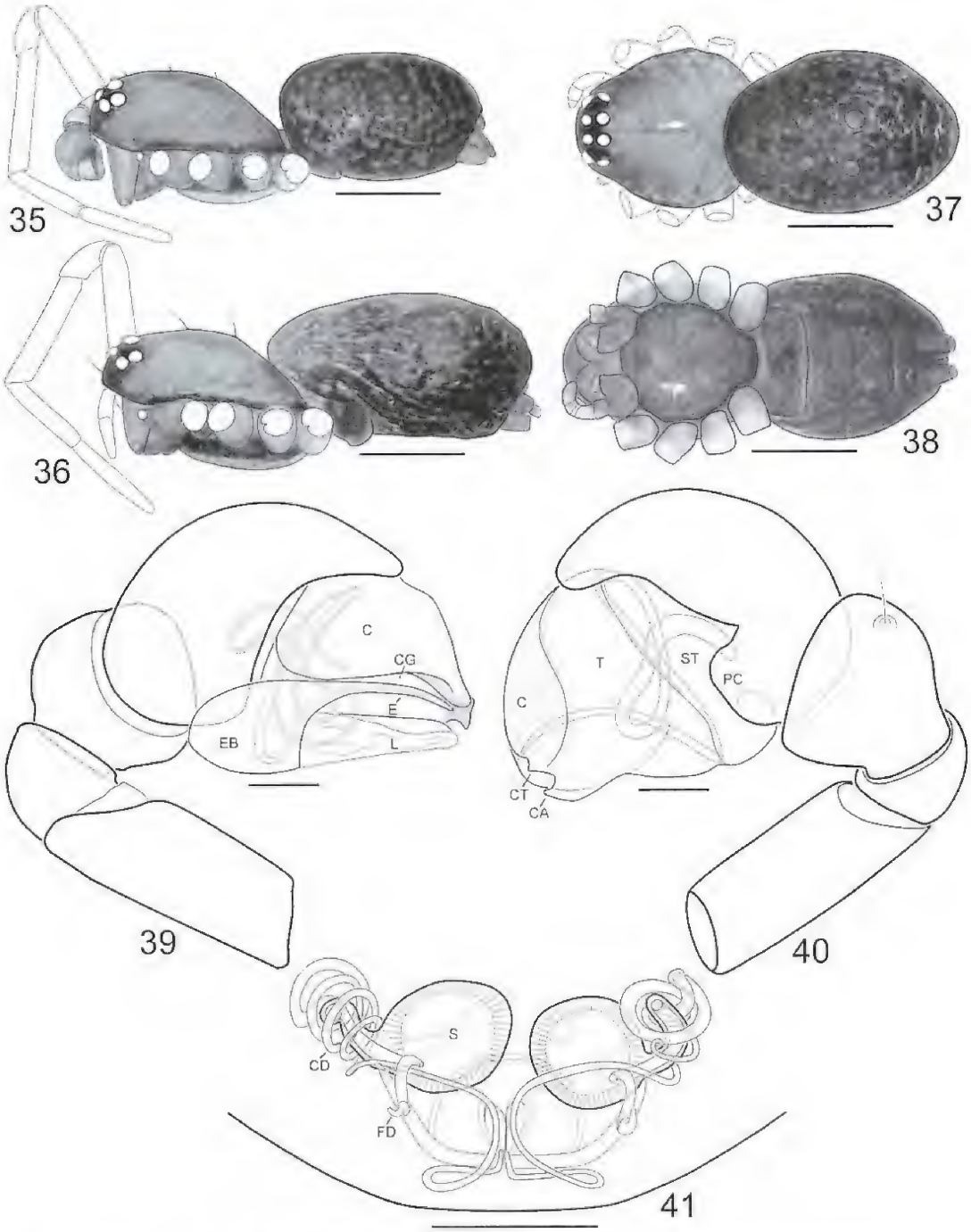
FIGURES 17–22. *Africepheia madagascariensis*, male palp. 17. Prolateral. 18. Retrolateral. 19. Ventral. 20. Proximal part of tegulum showing terminal and subterminal apophyses and embolic tip. 21. Apical. 22. Dorsal. Scale bars: 17, 22 = 20 μm; 18–19, 21 = 30 μm; 20 = 10 μm. For abbreviations see Table 1 (p. 22).



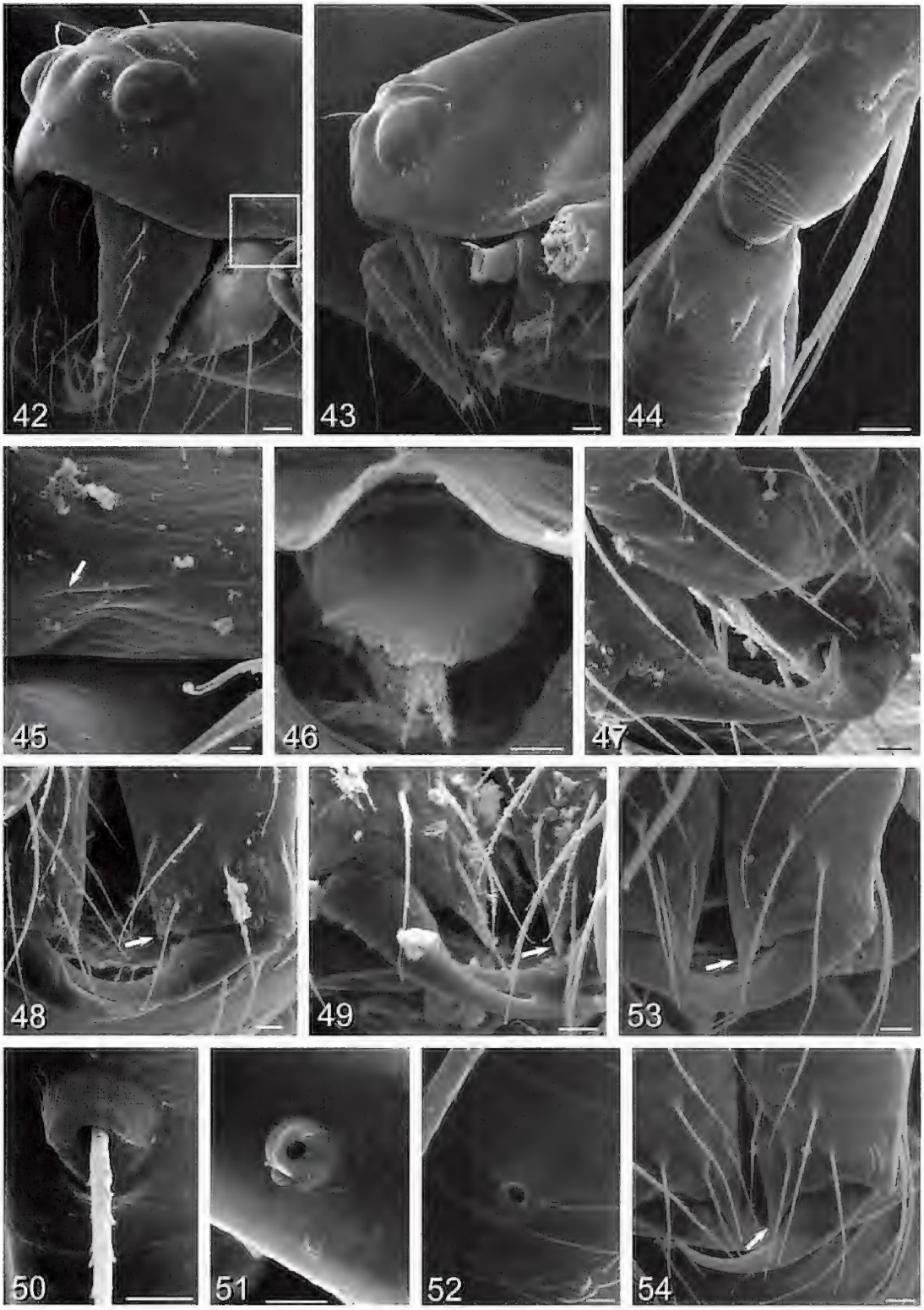
FIGURES 23–28. 23–27. *Africepheia madagascariensis*; 28. *Synaphris schlingeri*. 23–25, 27–28, female; 26, male. 23–24. Epigynum. 23. Ventral. 24. Lateral. 25. Posterior part of abdomen, ventral view, arrow indicates one of two tracheal openings. 26. Epiandrous gland spigots, one of four indicated by arrow. 27–28. Cleared epigynum, dorsal. Scale bars: 23–24, 26 = 10 μm; 25 = 20 μm; 27–28 = 0.05 mm. For abbreviations see Table 1 (p. 22).



FIGURES 29–34. *Africepheia madagascariensis*. 29–32, female; 33–34, male. 29, 33. Spinnerets. 30, 34. Posterior lateral spinneret. 31. Posterior median spinnerets. 32. Anterior lateral spinneret. Scale bars: 29 = 20 µm; 30–32 = 3 µm; 33 = 10 µm; 34 = 2 µm. For abbreviations see Table 1 (p. 22).



FIGURES 35–41. *Synaphris schlingeri*. 35, 39–40, male; 36–38, 41, female. 35–36. Habitus, lateral. 37. Habitus, dorsal. 38. Habitus, ventral. 39–40. Palp. 39. Prolateral. 40. Retrolateral. 41. Cleared epigynum, dorsal. Scale bars: 35–38 = 0.2 mm; 39–41 = 0.05 mm. For abbreviations see Table 1 (p. 22).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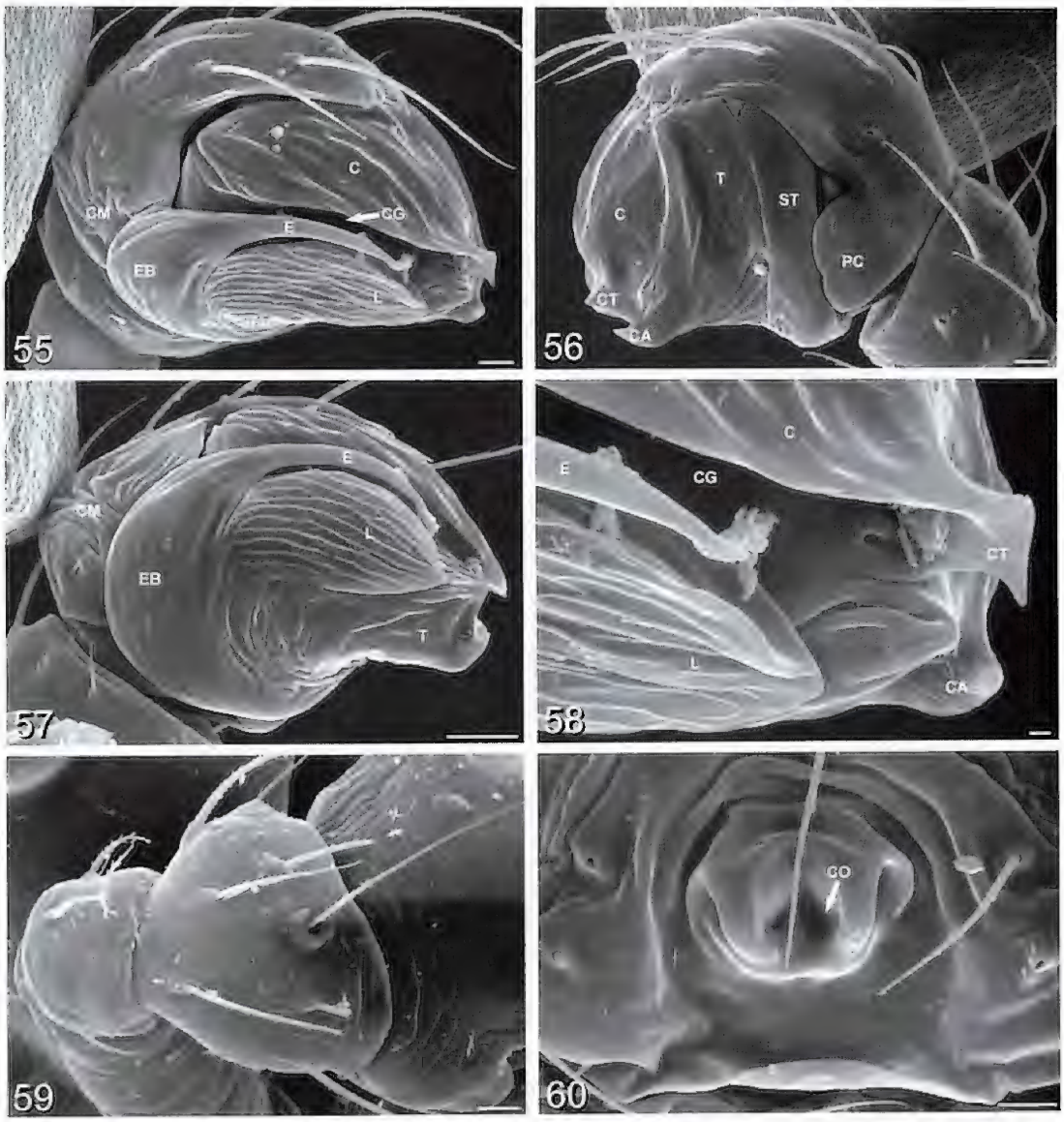
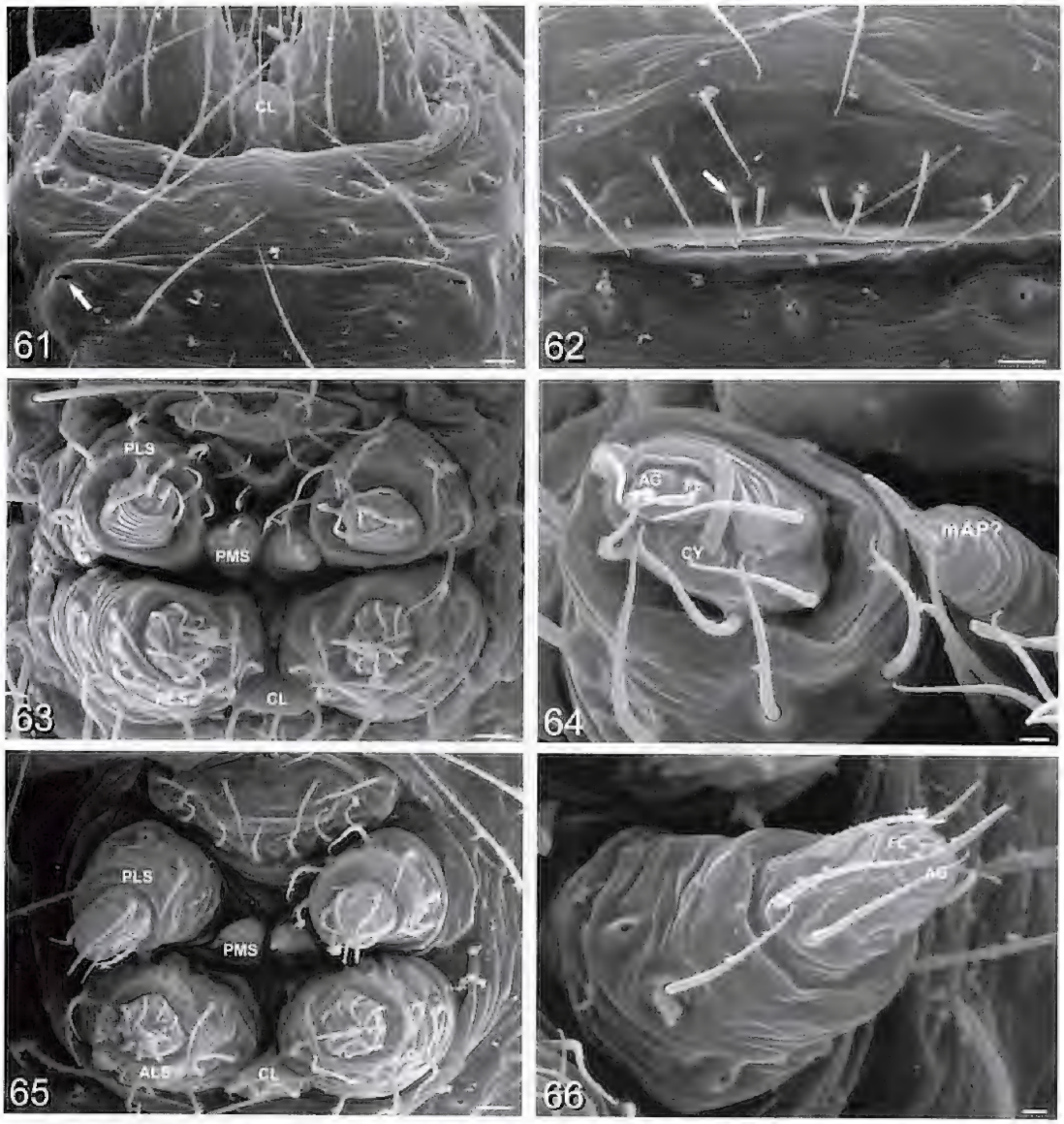
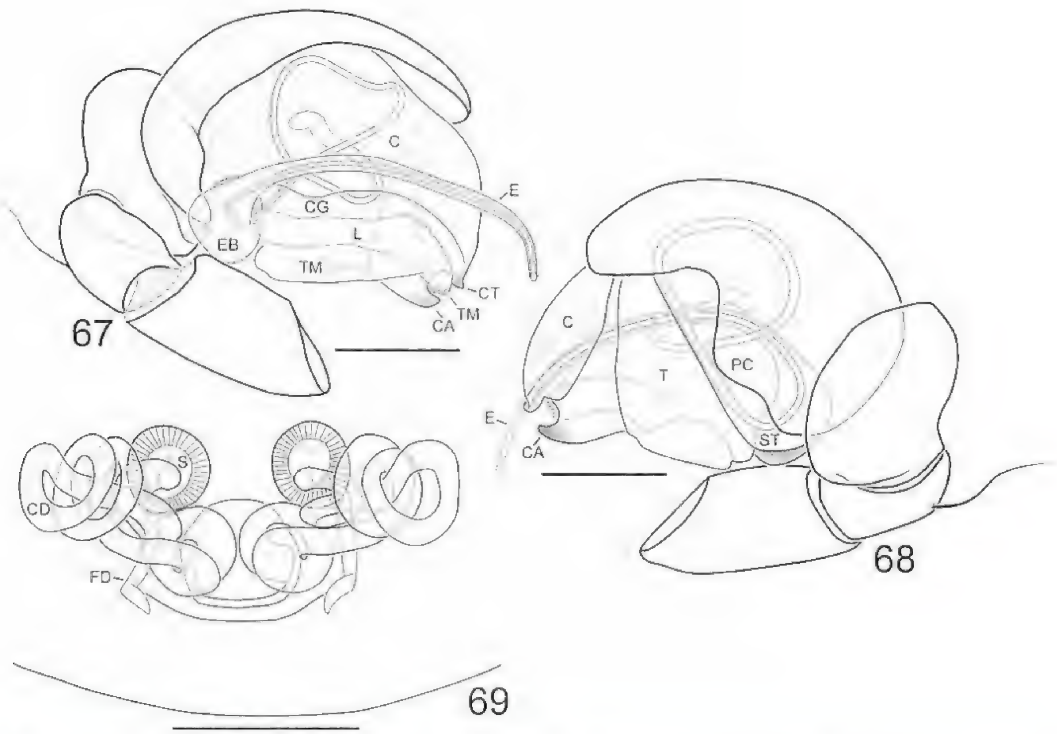


FIGURES 55–60. *Synaphris schlingeri*. 55–59, male palp; 60, epigynum. 55. Prolateral. 56. Retrolateral. 57. Ventral. 58. Distal part of tegulum showing terminal and subterminal apophyses and embolic tip. 59. Palpal tibia, dorsal. 60. Ventral. Scale bars: 55–56, 59–60 = 10 μm; 57 = 20 μm; 58 = 2 μm. For abbreviations see Table 1 (p. 22).

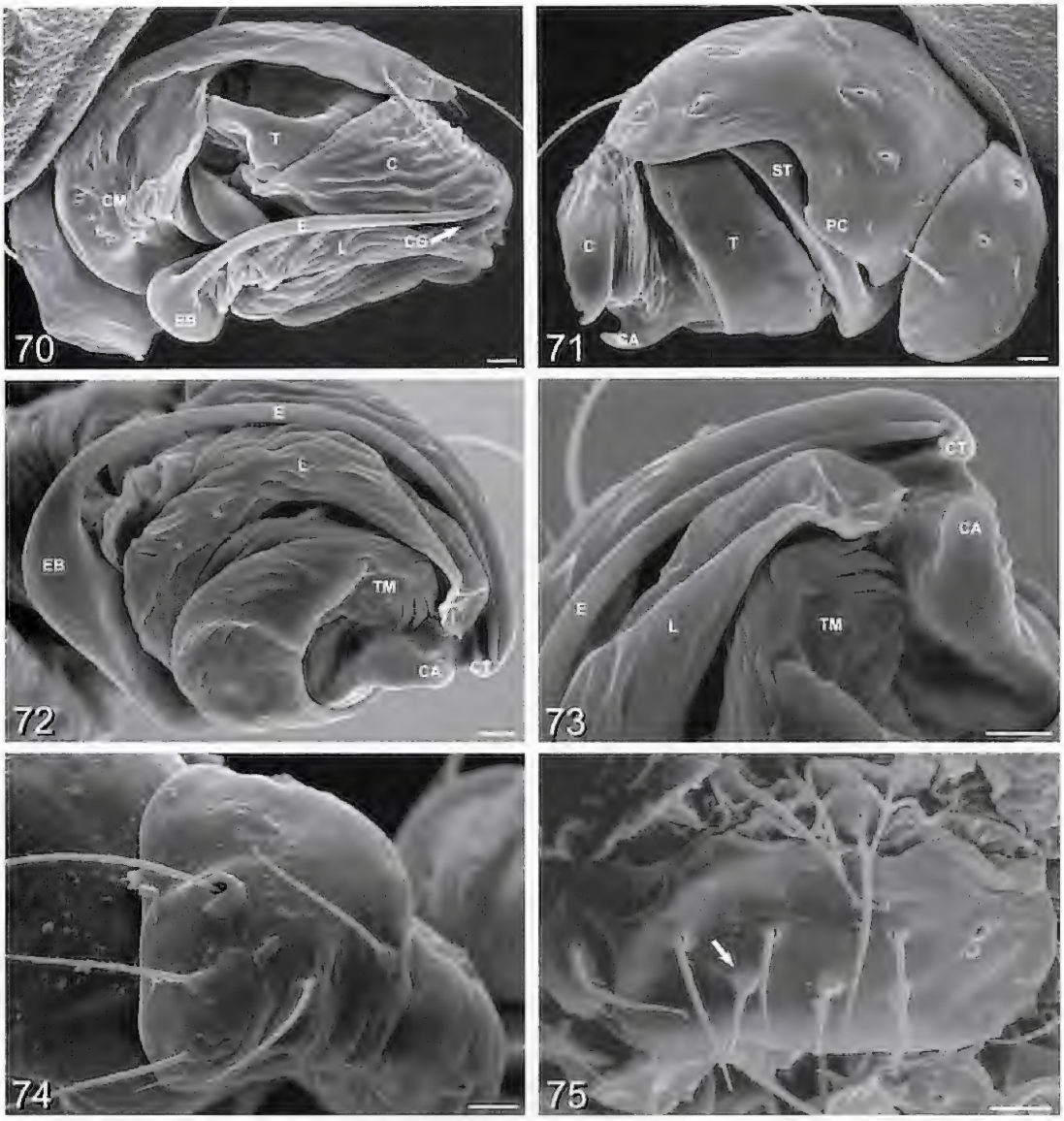
FIGURES 42–54 (left). 42–52, *Synaphris schlingeri*; 53–54, *Synaphris toliara*. 42, 45, 47–48, 53, male; 43–44, 46, 49–52, 54, female. 42–43. Anterior part of prosoma, lateral. 44. Junction of metatarsus and tibia I, note tapered tip of metatarsus and transverse ridges. 45. Sulcus, detail of area indicated by box in 42, arrow indicates pore. 46. Labrum. 47. Chelicerae, posterior view. 48–49, 53–54. Chelicera, anterior, arrow indicates keel. 50. Trichobothrium on metatarsus I. 51. Bothrium (hair lost) on tibia I. 52. Tarsal organ. Scale bars: 42–43 = 20 μm; 44, 46–51, 53–54 = 10 μm; 45 = 3 μm; 52 = 2 μm.



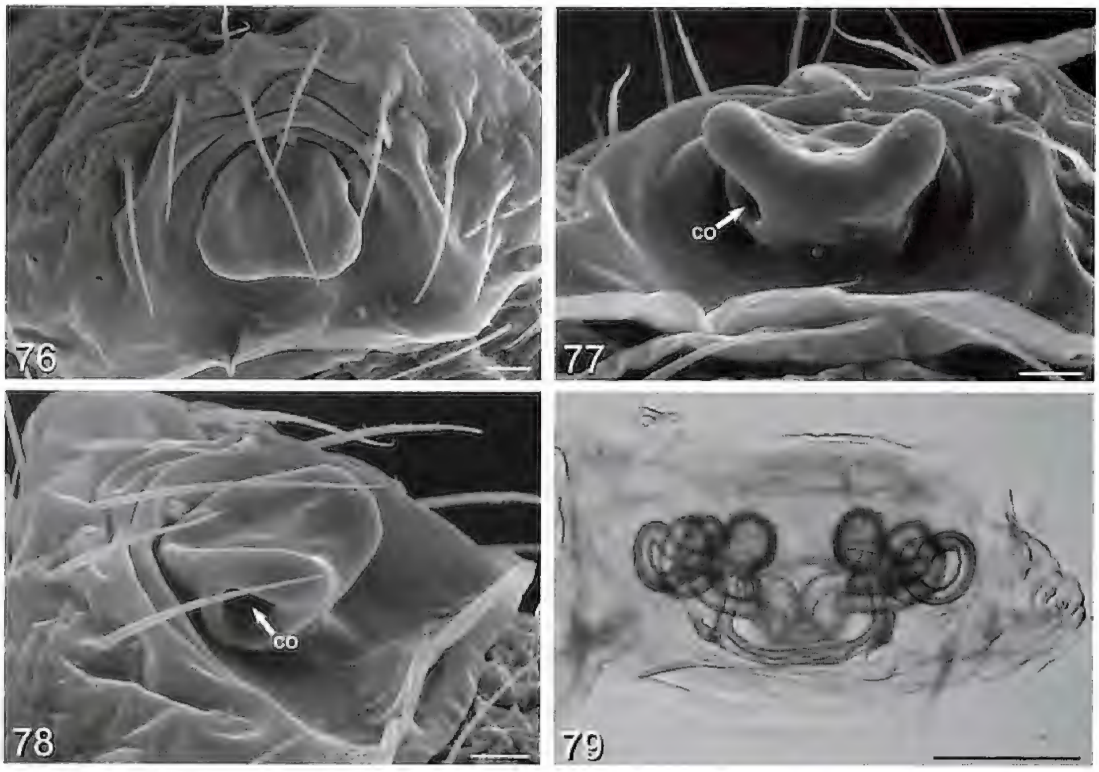
FIGURES 61–66. *Synaphris schlingeri*. 61, 63–64, female; 62, 65–66, male. 61. Posterior part of abdomen, ventral view, arrow indicates one of two tracheal openings. 62. Epiandrous gland spigots, one of four indicated by arrow. 63, 65. Spinnerets. 64. Posterior lateral and posterior median spinnerets. 66. Posterior lateral spinneret. Scale bars: 61–63, 65 = 10 µm; 64, 66 = 3 µm. For abbreviations see Table 1 (p. 22).



FIGURES 67–69. *Synaphris toliara*. 67. Male palp, prolateral. 68. Male palp, retrolateral. 69. Cleared epigynum, dorsal. Scale bars = 0.05 mm. For abbreviations see Table 1 (p. 22).



FIGURES 70–75. *Synaphris toliara*, male. 70–74, palp; 75, epiandrous region. 70. Prolateral. 71. Retrolateral. 72. Ventral. 73. Distal part of tegulum showing terminal and subterminal apophyses and tips of lamella and embolus. 74. Palpal tibia, dorsal. 75. Epiandrous gland spigots, one of three indicated by arrow. Scale bars = 10 μm. For abbreviations see Table 1 (p. 22).



FIGURES 76–79. *Synaphris toliara*, epigynum. 76. Ventral. 77. Posterior. 78. Lateral. 79. Cleared, dorsal. Scale bars: 76–78 = 10 μm; 79 = 0.05 mm. For abbreviations see Table 1 (p. 22).

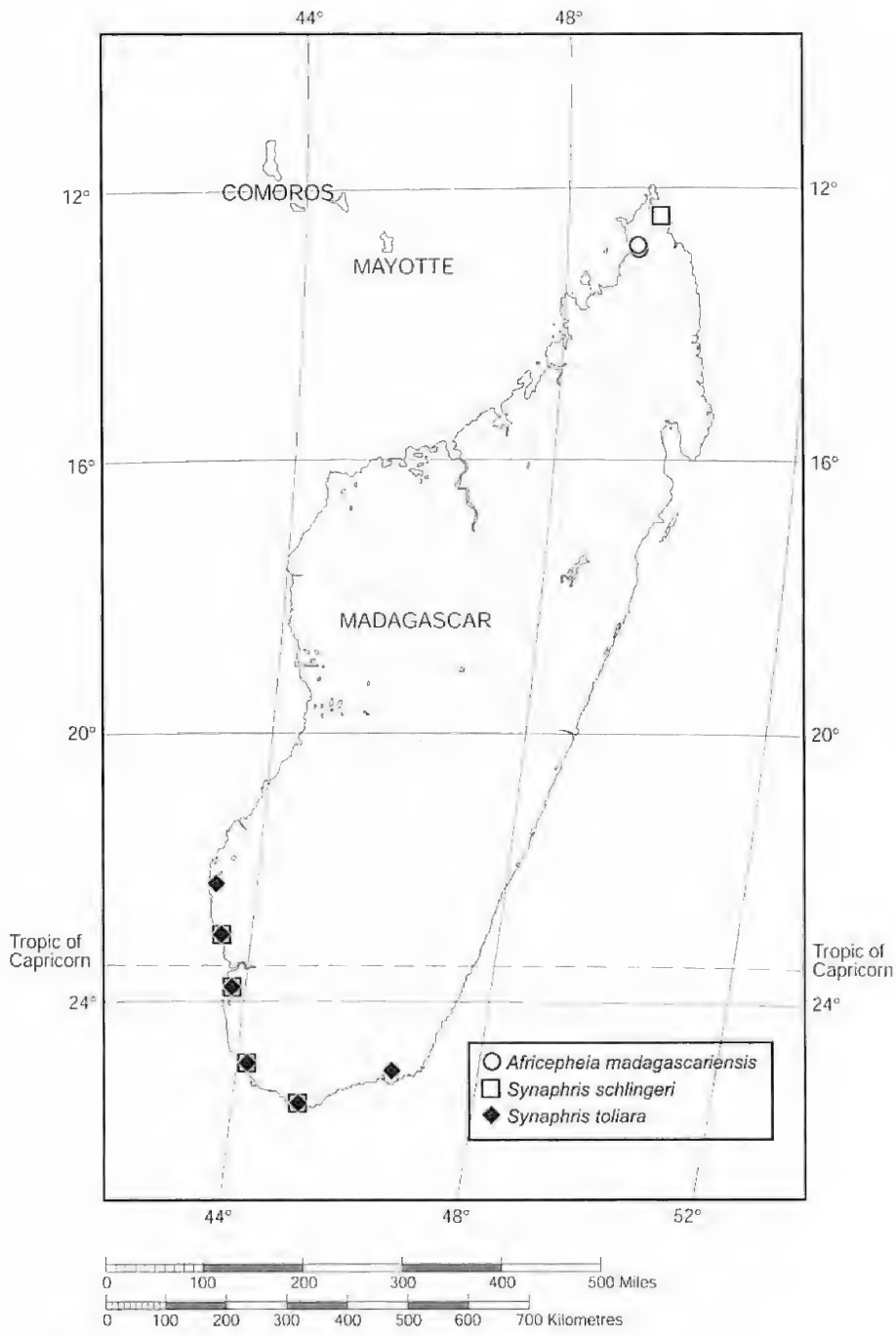


FIGURE 80. Distribution of synaphrid species in Madagascar.

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Four New Species of the Subgenus *Leptoferonia* Casey (Coleoptera, Carabidae, *Pterostichus* Bonelli) from California

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Four small, nearly eyeless species, *Pterostichus* (*Leptoferonia*) *blodgettensis*, *P.* (*Leptoferonia*) *pemphredo* (both with type locality Blodgett Experimental Forest, Eldorado Co. California), *P.* (*Leptoferonia*) *deino* (type locality Deer Creek Meadow, Tehama Co. California), and *P.* (*Leptoferonia*) *enyo*, (type locality, 12 mi west of Weaverville, Trinity Co. California) are described. These species are known from very few specimens but are highly distinctive in body form, male genitalic shape and in having extremely small eyes. These species represent three separate evolutionary events in *Leptoferonia* resulting in size and eye reduction.

Pterostichus Bonelli is one of the few groups of relatively large-sized carabid beetles in North America that needs significant revision. The classification of this genus has been subjected to bouts of lumping and splitting of generic and subgeneric taxa throughout its taxonomic history. Presently, there are approximately 75 recognized subgenera worldwide. In North America, the tribe Pterostichini includes 12 genera, of which two, *Abaris* Dejean and *Hybothecus* Chaudoir (= *Ophryogaster* Chaudoir), are more closely related to South American taxa and one, *Abax* Schuler, is a recent introduction from Europe. The remaining genera (excluding Loxandrini) are more or less closely related to *Pterostichus*, and many of them have been included in a larger concept of that genus by various authors. The relationships among the 21 North American and several Mexican subgenera of *Pterostichus*, and between these taxa and the numerous Palearctic subgenera is still unresolved. However, significant advances have been made in one part of *Pterostichus*, the *Hypherpes*-complex. Recent classifications have placed the taxa of this complex, which includes species placed by various authors in *Leptoferonia* Casey, *Anilliferonia* Van Dyke, and *Hypherpes* Chaudoir together in the single subgenus *Hypherpes*. Based on adult and larval morphology, which provide few obviously decisive grouping characters for the subgenera (Bousquet 1999), this was a reasonable solution. Exemplar DNA sequence analysis of taxa of the *Hypherpes*-complex using three gene loci showed that the three subgenera of *Pterostichus* (*Leptoferonia, Anilliferonia* and *Hypherpes*) do form a single clade relative to other North American and select Palearctic subgenera. *Leptoferonia* and *Hypherpes* are reciprocally monophyletic and *Anilliferonia* is monophyletic, exclusive of *Anilloferonia rothi* (Hatch), which is a member of *Leptoferonia* (K.Will and A.Gill, unpublished). Therefore, the species treated herein are described in *Leptoferonia*.

Recent publications on North American *Pterostichus* (Bousquet 1999) and descriptions of new species of the subgenus *Hypherpes* all point out that there are a great many new species to describe in *Hypherpes* s.str. (Kavanaugh and LaBonte 2006; LaBonte 2006). The last treatment of *Hypherpes*, exclusive of *Leptoferonia*, was done by Casey (1913, 1924). My examination of available specimens of *Leptoferonia* suggests that the more thorough study done by Hacker (1968)

leaves relatively few species to be described in that subgenus. Notwithstanding the quality of Hacker's treatment, study of recently collected specimens and specimens found in various collections revealed the presence of four highly distinctive new species of *Leptoferonia*. The purpose of this contribution is to describe and name these newly discovered taxa.

Materials and Methods

More than 600 adult specimens of *Leptoferonia* were examined for this study, and these represent all named species. Specimens pertinent to this study are deposited in the Essig Museum of Entomology Collection, University of California, Berkeley (EMEC) and the California Academy of Sciences, San Francisco (CAS). Specimen dissection protocols, taxonomic methods, and species recognition criteria follow Will (2002). Specimens and their dissected elements were examined using a dissecting microscope with magnification ranging from 25–100×. An ocular scale micrometer was used to take measurements. Total body length is the sum of the length of the elytra along the midline from basal margin to apex, plus length of pronotum from base to apices of anterior angles, plus head length from anterior margin of pronotum to base of mandibles. Habitus and genitalia images were taken using a Microptics XLT digital imaging system. Line drawings of male genitalia, female reproductive tract, and pronota were composed in standard image editing software by overlaying digital images and tracing them using a drawing tablet.

Taxonomic Treatment

***Pterostichus (Leptoferonia) blodgettensis* Will, sp. nov.**
Figures 1A, 2A, 3A–D, 4.

Types.— Holotype: Point mounted male, labeled: "38°54′45″N/120°39′26″W, USA: **California**: El Dorado Co., Blodgett Experimental Forest, Bacon Crk nr Loop Rd. 1250 m el., 3.xii.2004. Coll. K. & O.Will, Under rotten log." Deposited EMEC. Partially disarticulated and tissue used for DNA extraction. Template DNA labeled "kww368".

Description.— *Color*: rufous throughout. *Total body length*: 6.0 mm. *Ventral surface*: Prothoracic venter smooth, mesepimeron and lateral portion of the metasternum shallowly punctate, abdomen without punctuation. *Head*: Moderately broad, width of head at widest point 7/10 width of pronotum at widest point. Eye minute, 0.10 mm over greatest length, narrow oval form. Frontal impressions divergent. Antennae of average build, total length reaching slightly beyond base of pronotum, antennomeres 5–10 elongate form. *Pronotum* (Fig. 1A): Greatest width and length equal, widest well before midpoint, sides nearly parallel and slightly convergent to base and straight onto nearly rectangular hind angles. Anterior corners markedly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner linear and outer absent. Base smooth. Anterior lateral setae less than one quarter pronotum length from anterior margin, basal setae set in hind angles. *Elytra* (Fig. 2A): Form parallel-sided, base with border entire, humeral angle with prominent tooth, parascutellar setiferous punctures absent, parascutellar stria not connected to stria 1, angular base of stria 1 present, connected or not to stria 1, nine well-impressed striae, striae smooth throughout, margin at epiplura carinate with well defined bead for its entire length, no external plica. Umbilicate series of stria 8 with six setiferous punctures in anterior (basal) series, no punctures in medial series, six in posterior (apical) series and a single puncture near apex of stria 7. *Legs*: Average build, metatrochanter blunt, meta coxa with one seta near base and one near medial edge, tarsi moderately elongate, fifth tarsomere ventrally glabrous. Male protarsi slightly, symmetrically expanded, with ventral articulo-setae. *Sixth abdominal ventrite*: Male with two

seta, medial concavity and preapical, low thick ridge. *Aedeagus* (Fig. 3A–D): Meeting of ventral surface and right-lateral surface of median lobe with elevated carina, ventral surface concave with lightly sclerotized diagonal strip. Tip relatively short and bluntly rounded. Right paramere short, broadly rounded at apex. Internal sac without sclerotized spine. *Pygidial glands*: Reservoirs somewhat cordiform, no additional lobes on reservoir or efferent duct.

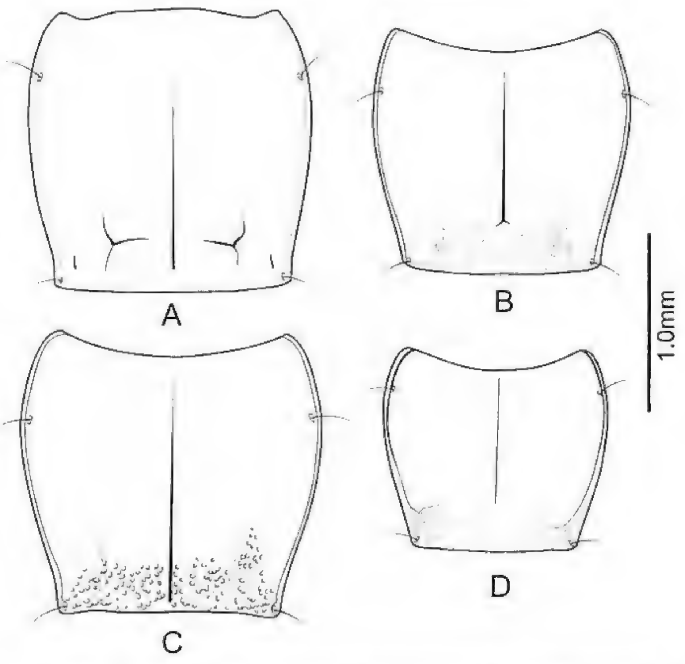

FIGURE 1. Pronota. A. *Pterostichus blodgettensis*; B. *P. pemphredo*; C. *P. deino*; D. *P. enyo*.

SPECIMENS EXAMINED.— Type specimen only.

DISTRIBUTION.— Known only from the type locality, Blodgett Experimental Forest, Eldorado Co. California (Fig. 4).

REMARKS.— I collected a single specimen under a deeply set, large rotten log in a shaded area near Bacon Creek. The soil was relatively moist, but not saturated. Microhabitat is the same as *P. pemphredo*, and although they were not collected together under a single log, they were under adjacent ones. Other species of *Leptoferonia* found in the area, but not under deep-set logs, include *P. inanis* Horn and *P. hatchi* (Hacker).

ETYMOLOGY.— Named after the type locality.

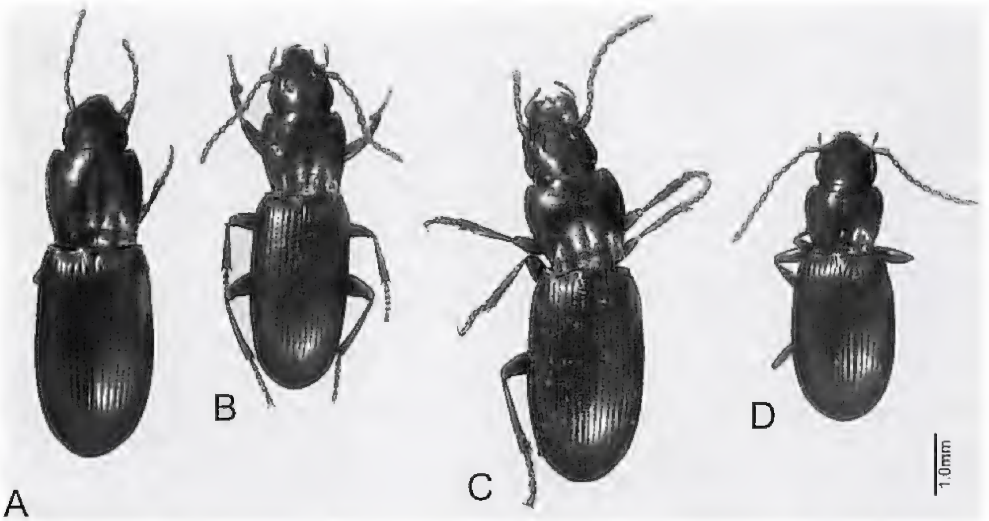

FIGURE 2. Images of habitus. A. *Pterostichus blodgettensis*; B. *P. pemphredo*; C. *P. deino*; D. *P. enyo*.

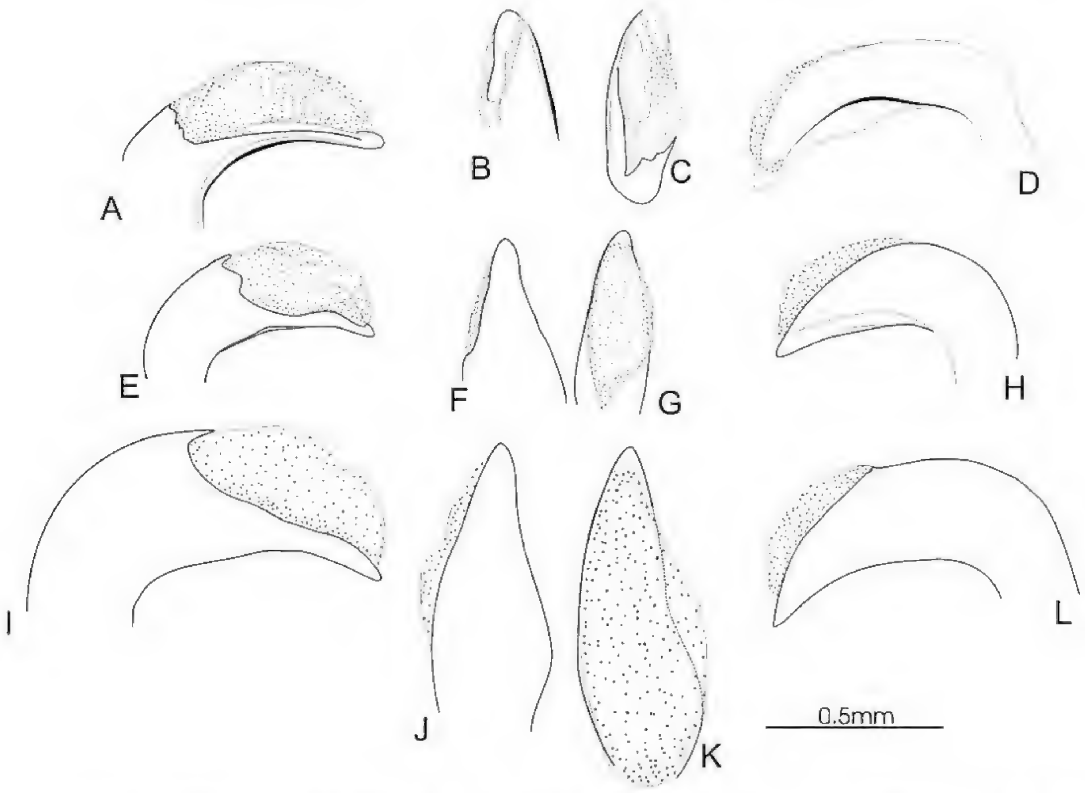

FIGURE 3. Median lobe of the aedeagus. A. left lateral view, B.ventral view of tip, C. dorsal view of tip, D. right lateral view for *Pterostichus blodgettensis*; E–H, same for *P. pemphredo*; I–L, same for *P. deino*.

Pterostichus (*Leptoferonia*) *pemphredo* Will, sp. nov.

Figures 1B, 2B, 3E–H, 4, 5.

TYPES.— HOLOTYPE: Point mounted female, labeled: "38°54′45″N/120°39′26″W, USA: **California:** El Dorado Co., Blodgett Experimental Forest, Bacon Crk nr Loop Rd. 1250 m el., 5.vi.2004. Coll. K.Will, Under rotten log nr stream." Deposited EMEC. ALLOTYPE: Point mounted male, labeled: "CALF. El Dorado Co., Blodgett Forest, 13 mi. E. Georgetown, el. 4000–4500′; 29 May 1971, Robert Hislop. Univ. Calif. Insect Survey Specimen # 109722." Deposited EMEC. PARATYPES: Vial storage in EtOH 1 male, 1 female, both with same label data and deposition as holotype, both with genitalia dissected, male further disarticulated and tissue used for DNA extraction. Template DNA labeled "kww240." Deposited EMEC. 1 female, point mounted, with same label data and deposition as holotype. Deposited CAS.

DESCRIPTION.— *Color*: rufous throughout. *Total body length*: 5.8 mm (range of paratypes 5.6–5.8 mm). *Ventral surface*: Lateral portion of thorax and abdomen distinctly punctate. *Head*: Relatively broad, width of head at widest point ⅘ width of pronotum at widest point. Eye minute, 0.10 mm over greatest length, narrow oval form. Frontal impressions divergent posteriorly. Antennae relatively short and stout, total length not reaching base of pronotum, antennomeres 5–10 quadrate form. *Pronotum* (Fig. 1B): Greatest width slightly more than greatest length, widest well before midpoint, sides scarcely rounded and convergent to base where they are straight onto nearly rectangular hind angles. Anterior angles very slightly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner linear and broadly joined to outer that ends laterally at a low, rounded carina. Entire base lightly punctate. Anterior lateral setae

one quarter pronotum length from anterior margin, basal setae approximately width of puncture forward of base. *Elytra* (Fig. 2B): Form parallel-sided, base with border entire, humeral angle with prominent tooth, parascutellar setiferous punctures absent, angular base of stria 1 absent, nine well-impressed striae, striae distinctly punctate in basal two thirds, shallowly punctate to smooth in apical third, margin at epiplura rounded in apical two thirds, carinate in basal third, no external plica. Umbilicate series of stria 8 with five setiferous punctures in anterior (basal) series, no punctures in medial series, five in posterior (apical) series and a single puncture near apex of stria 7. *Legs*: Average build, metatrochanter bluntly pointed, more slender in male, meta coxa with single seta near base (one paratype female with extremely short, fine seta near median margin), tarsi stout, fifth tarsomere ventrally glabrous. Male protarsi slightly, symmetrically expanded, with ventral articulo-setae. *Sixth abdominal ventrite*: Female with four setae, male with two. Male apex unmodified. *Aedeagus* (Fig. 3E–H): Meeting of ventral surface and right-lateral surface of median lobe slightly carinate, ventral surface without lightly sclerotized strip. Tip relatively long and pointed. Right paramere short. Internal sac with large, sclerotized spine. *Female reproductive tract* (Fig. 5): Bursa cup-shaped; spermathecal duct very elongate, length about 16× of that of gonocoxite-1; spermatheca elongate, smooth; appended spermathecal gland elongate, subtended by ampulla and connected by duct near base of spermatheca; gonocoxite-1 with 1–2 apicolatera ensiform setae, gonocoxite-2 with 2–3 lateral and 1 dorsomedial ensiform setae and 2 nematiform setae in elongate subapical furrow. *Pygidial glands*: Simple, without modification of reservoir or efferent duct.

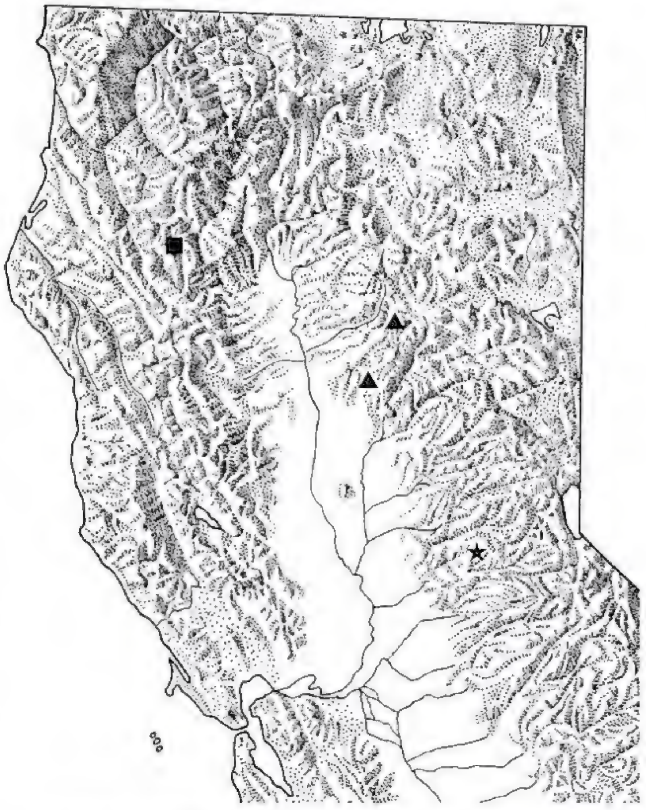

FIGURE 4. Northern California localities for *Pterostichus blodgettensis*, star; *P. pemphredo*, star; *P. deino*, triangle; D. *P. enyo*, square.

SPECIMENS EXAMINED.— Five individuals of type series.

DISTRIBUTION.— Known only from the type locality, Blodgett Experimental Forest, El Dorado Co., California (Fig. 4).

REMARKS.— I collected four specimens near Bacon Creek. The soil was moist, but not saturated. All four where found under deeply set, large rotten logs in shaded areas. Additionally, the field notes related to the specimen labeled 'Calif. Insect Survey Specimen # 109722' indicate that this specimen was found to be active under an old, rotten log in wet soil. Microhabitat is the same as *P. blodgetti*, and although they were not collected together under a single log, they were under adjacent ones. Other species of *Leptoferonia* found in the area, but not under deep-set logs, include *P. inanis* Horn and *P. hatchi* (Hacker).

ETYMOLOGY.— Named as a noun in apposition after *Pemphredo* ("Alarm"), one of the three Graeae, daughters of Phorcys and Ceto from Greek mythology. These sisters are said to share one eye among them. This is analogous to the three minute-eyed species of beetle described herein, which are named after the *Graeae*, as they scarcely have a single eye among them.

***Pterostichus* (*Leptoferonia*) *deino* Will, sp. nov.**

Fig. 1C, 2C, 3I–L, 4.

TYPES.— HOLOTYPE: Point mounted female, labeled: "Chico-Chester, Deer Ck. Meadow, Cal. 6-17-1956, P.S. Bartholemow// P.S. Bartholomew collection, Calif. Acad. Sci. Accession 1967". Deposited CAS. ALLOTYPE: Point mounted male, genitalia dissected in vial, labeled: "Chico El. 2200, Forest Ranch, Cal. 6-17-1956, P.S. Bartholemew// P.S. Bartholomew collection, Calif. Acad. Sci. Accession 1967". Deposited CAS.

DESCRIPTION.— *Color*: rufous throughout. *Total body length*: 6.0 mm (allotype 6.9 mm). *Ventral surface*: Lateral portion of thorax distinctly punctate, abdomen smooth. *Head*: Relatively broad, width of head at widest point ¾ width of pronotum at widest point. Eye minute, 1.0 mm over greatest length, narrow obovate form. Frontal impressions divergent. Antennae relatively short and somewhat stout, total length scarcely reaching base of pronotum, antennomeres 5–10 nearly quadrate form. *Pronotum* (Fig. 1C): Greatest width slightly more than greatest length, widest well before midpoint, sides scarcely rounded and convergent to base where they are straight onto rectangular hind angles. Anterior corners slightly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner broad, linear and joined to outer that ends laterally at a low, rounded carina. Entire base coarsely punctate. Anterior lateral setae slightly less than one third pronotum length from anterior margin, basal setae approximately half width of puncture forward of base. *Elytra* (Fig. 2C): Form parallel-sided, base with border entire, humeral angle with prominent tooth, parascutellar setiferous punctures absent, parascutellar stria connected to stria 1, angular base of stria 1 absent in holotype present in allotype, nine well-impressed striae, striae distinctly punctate in basal

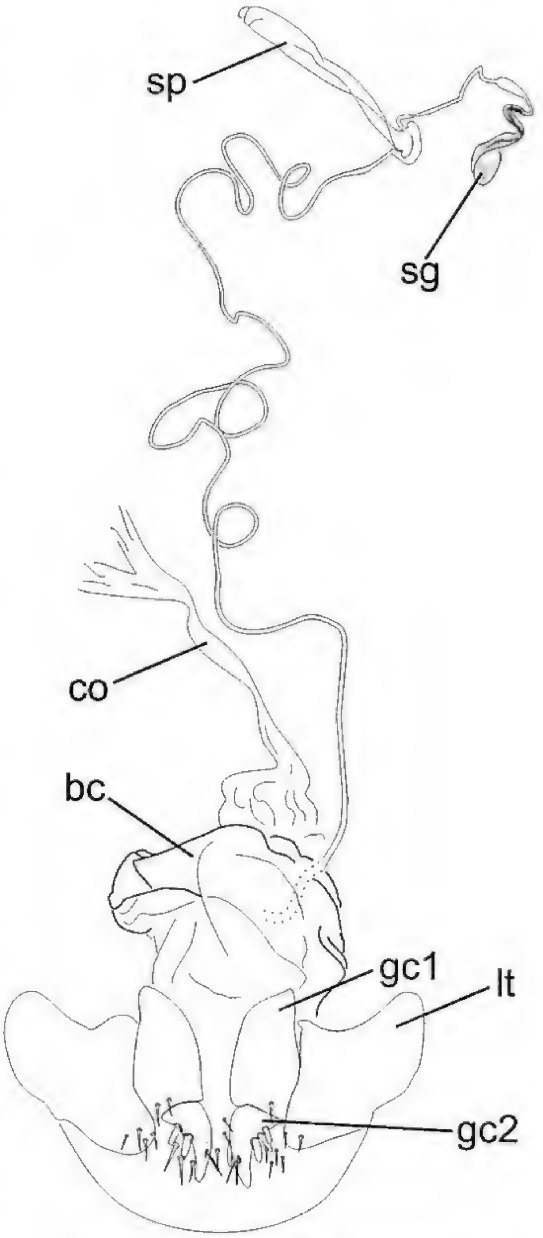

FIGURE 5. Female reproductive tract. *Pterostichus pemphredo*; bc, bursa copulatrix; co, common oviduct; gc1, gonocoxite-1; gc2, gonocoxite-2; lt, laterotergite IX; sg, appended spermathecal gland; sp, spermatheca.

two thirds, shallowly punctate in apical third, margin at epiplura rounded in apical two thirds, marginal bead scarcely apparent, carinate in basal third, no external plica. Umbilicate series of stria 8 with five setiferous punctures in anterior (basal) series, no punctures in medial series, five in posterior (apical) series and a single puncture near apex of stria 7. *Legs*: Average build, metatrochanter acutely pointed, more slender and with more attenuated apex in male, meta coxa seta near base and near median margin, pro- and mesotarsi stout, metatarsi more elongate, fifth tarsomere ventrally glabrous. Male protarsi slightly, symmetrically expanded, with ventral articulo-setae. *Sixth abdominal ventrite*: Female with four setae, male with two. Male apex unmodified. *Aedeagus* (Fig. 3I–L): Meeting of ventral surface and right-lateral surface of median lobe carinate, ventral surface without lightly sclerotized strip. Tip long, acuminate and pointed at apex. Right paramere short. Internal sac with large, broad sclerotized spine. Female reproductive tract not studied.

Specimens examined.— Two individuals of type series.

Distribution.— Known from the type locality, Deer Creek Meadow, Tehama Co. California, estimated coordinates 40°16′10″N 121°26′00″W, 1600 m el., and Forest Ranch, Butte Co. California, estimated coordinates 39°53′07″N 121°40′27″W, 730 m el.

Etymology.— Named as a noun in apposition for *Deino* ("Dread") of Greek mythology. See further explanation under *P. pemphredo*.

Pterostichus (*Leptoferonia*) *enyo* Will, sp. nov.

Fig. 1D, 2D, 4.

Types.— Holotype: Point mounted female, labeled "USA: California: Trinity Co.: 12 mi. W. Weaverville, 2.3–6.8 mi N. on FR 421, 1700–2000 ft., V-29-96, litter nr. stream, L. Herman." Deposited AMNH.

Description .— *Color*: light rufous. *Total body length*: 4.3 mm. *Ventral surface*: Lateral portions of thorax and abdomen distinctly punctate. Punctures on metasternum and metepisternum irregular and confluent. Punctures on abdominal ventrites 1–3 shallow, sparse to absent on remaining ventrites. *Head*: Relatively broad, width of head about as wide as pronotum, head at widest point $^{8}/_{10}$ width of pronotum at widest point. Frontal impressions well defined and sharply divergent posteriorly. Eye minute, 0.14 mm over greatest length, nearly as broad as long, obovate form. Antennae relatively average build, total length reaching well beyond base of pronotum, antennomeres 5–10 longer than wide. *Pronotum* (Fig. 1D): Greatest width $^{4}/_{5}$ length, widest point well before midpoint, sides scarcely rounded and convergent to base and obtuse hind angles. Anterior angles very slightly produced. Median line clearly impressed and near full length of pronotum. Basal impressions shallow, inner linear, divergent posteriorly, outer impression absent, area laterad of inner impression flat and depressed to margin. Median area of base very slightly punctulate. Anterior lateral setae one quarter pronotum length from anterior margin, basal setae approximately width of puncture forward of base. *Elytra* (Fig. 2D): Form slightly rounded, little ventricose, base with border entire, humeral angle with small tooth, parascutellar setiferous punctures absent, parascutellar stria present and free of stria 1, angular base of stria 1 present, nine well-impressed striae, striae shallowly punctate in basal two thirds to smooth in apical third, margin at epiplura carinate throughout, no external plica. Umbilicate series of stria 8 with five setiferous punctures in anterior (basal) series, one in medial series, four in posterior (apical) series and two puncture near apex of stria 7. *Legs*: Gracile build, metatrochanter bluntly pointed, meta coxa with seta near base and lateral margin of apex, tarsi average form, fifth tarsomere ventrally glabrous. *Sixth abdominal ventrite*: Female with four setae. Male unknown. Reproductive structures not studied.

Specimens examined.— Single holotype.

Distribution.— Known only from the type locality,12 mi west of Weaverville, Trinity Co. Ca., estimated coordinates 40°48′53″N 123°07′29″W.

Remarks.— Type locality is an area of Oak, Madrone and Poison Oak. Significant effort to collect additional specimens of this species at the type locality has not succeeded. No other species of *Leptoferonia* are known from the immediate type locality; however, I have found *P. humilis* Casey a few miles west and *P. inanis* a few miles north and east of the type locality.

Etymology.— Named as a noun in apposition for *Enyo* ("Horror") of Greek mythology. See further explanation under *P. pemphredo.*

Discussion

These four species have similar, characteristic eye reduction. However, only *P. pemphredo* and *P. deino* appear to be closely related to each other and these two near *P. caligans* Horn. All three of these species have a similarly modified margin of the elytral epiplura and general elytral form. They all share a rather parallel-side form and have the elytral margin rounded in the apical two-thirds with the marginal bead scarcely apparent such that the edge is carinate only in the basal third. Other species of *Leptoferonia* have the margin at epiplura carinate throughout its length. *Pterostichus enyo* is most likely related to *P. humilis* and *P. trinitensis* based on the general body form and similar shape of the pronotum. *Pterostichus blodgettensis* is related to *P. hatchi* based in both morphological similarities, such as the carina and concavity on the ventral surface of the median lobe of the aedeagus, the body-form and pronotal shape, and also DNA sequence data (K.Will and A.Gill unpublished).

Based on the relationships of these species alone, it appears that smaller body size and eye reduction have occurred at least three separate times in *Leptoferonia.* In the species described herein, the eyes are minute (relatively largest in *P. enyo*) and probably of limited function, and body size range is 4.3–6.9 mm. Other species of *Leptoferonia* range in body size from 5.5 mm to 12 mm, with the vast majority of species and specimens falling into the range of 7–9 mm (Hacker 1968). The specific habitat is known for *P. pemphredo*, *P. blodgettensis* and *P. enyo*. Although the sample size is extremely small, the three species seem to be associated with a persistent groundwater source and a surface stream that generally persists, but may not have a flow in the summer during extremely dry years. Probably these beetles evolved a more subterranean habit and concomitant eye reduction in response to California's seasonal rainfall patterns and frequent local droughts.

It is remarkable that two of these undescribed species were collected at the University of California's Blodgett Experimental Forest and that these specimens were found within a few meters of headquarters and researcher cabins. Many different aspects of the Blodgett property have been studied intensively over the more than 70 years that the property has belonged to the University of California. This includes numerous trips by entomologists and students of entomology. However, only a single specimen of one species was found among all specimens examined from those previous collecting efforts. In part, this is likely due to the strongly seasonal and somewhat cryptic nature of the beetles' life history. The discovery of these small and special species of carabid beetle points to two important facts: first, that there remains a great undescribed diversity of life under our feet in California and second, that state-owned and other public lands are important havens for many of these yet-to-be-discovered species.

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Mahafalytenus, a New Spider Genus from Madagascar (Araneae, Ctenidae)

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Among ctenid spiders, viridasines, largely restricted to Madagascar, are the most basal group of the family. A new genus of viridasine spiders, *Mahafalytenus*, is herein described. This genus is recognized by having a distinctive dorsal abdominal folium; palpal tarsus-tibia with long, prolateral bristles; and a unique male and female genitalic pattern. *Mahafalytenus tsilo* is designated as the type species. Six other species are also described: *M. fo, M. fohy, M. hafa, M. isalo, M. osy,* and *M. paosy*. A taxonomic key to the seven species currently known is herein provided. *Mahafalytenus* is found in a variety of habitat types ranging from spiny thicket vegetation to transitional forests. Most species appear to be restricted to the lowlands of southern Madagascar, only one species is known from a gallery forest at 850 m in south-central Madagascar.

KEYWORDS: Taxonomy, Viridasiinae, morphology, ctenids, spiders, southern Madagascar.

Ctenid spiders from Madagascar have never been revised. The current spider catalog (Platnick 2006) records only seven species, most of them known only from their original descriptions in the late 1800s (Griswold 2003). However, extensive field work in Madagascar in recent years is revealing a richer ctenid spider fauna at both genus and species level. Among these new taxa, viridasine spiders (Lehtinen 1967) are the most species rich and abundant group, comprising at least four genera, of which, two are new to science. Viridasiinae is the sister group to all other ctenid spiders (Silva Dávila 2003), therefore, a key group for understanding the phylogenetic relationships within this family as well as its relationships to other higher groups. In this paper, a new viridasine genus, *Mahafalytenus*, is described. The somatic and genitalic characters shown by this new taxon will greatly contribute to a refinement of a previous phylogenetic hypothesis regarding ctenids and viridasines, in particular. *Mahafalytenus* comprises medium to large spiders, males and females are easily recognized by having 1) a well marked, distinctive abdominal folium; 2) long, prolateral bristles beneath palpal tibia-tarsus; and most important 3) a very distinctive genitalic pattern. As with many other Malagasy ctenid spiders, most species of *Mahafalytenus* show very narrow distributions and in spite of their conspicuousness, exhaustive spider collecting, and examination of various museum collections, they appear to be actually rare. However, this rarity effect could also indicate they are highly seasonal and that a sampling at the right time of the year is still lacking. Further fieldwork will undoubtedly yield additional new species of this taxon, and, luckily, more data about their natural history and distribution patterns.

Materials and Methods

Specimens were examined following standard procedures for spiders. All measurements are in millimeters. Species descriptions are based upon a single individual, locality noted in parentheses. Digital images were made with a Leica M420 stereomicroscope and a JVC-KY-F75U digital camera plus the auto-montage software by Syncroscopy Ltd.

Abbreviations.— AC, aciniform gland spigots; AER, anterior ocular row at their greatest width; AME, anterior median eyes; ALE, anterior lateral eyes; ALS, anterior lateral spinnerets; AN, anelli of subtegulum; BS, base of spermatheca; C, conductor; Ca, apex of conductor; Cb, base of conductor; CD, copulatory duct; CY, cylindrical gland spigots; E, embolus; FD, fertilization duct; HS, head of spermatheca; la = lamella of conductor, LL, lateral lobes of epigynum; MA, median apophysis; MAP, major ampullate gland spigots; mAP, minor ampullate gland spigots; MaTP, *Mahafalytenus* tegular process; MS, median sector of epigynum; nu, nubbin; OQA, ocular quadrangle, width of anterior median eye row; OQL, ocular quadrangle length at the greatest distance from AME to PME in frontal view; OQP, ocular quadrangle, width of posterior median eye row; Pe, petiole; PI, piriform gland spigots; PME, posterior median eye; PLE, posterior lateral eye; PER, posterior ocular row at their greatest width; PLS, posterior lateral spinnerets; PMS, posterior median spinnerets; RDTP, retrodorsal tibial process; RTA, retrolateral tibial apophysis; ST, subtegulum; st, stalk of spermatheca; T, tegulum; ta, tartipore; VLTP, ventrolateral tibial process.

Museum collections: CAS – California Academy of Sciences, San Francisco (C. Griswold); FMNH – Field Museum of Natural History, Chicago (P.P. Parrillo, P. Sierwald).

Taxonomy

Mahafalytenus Silva-Dávila, gen. nov.

Figures 1–27; Maps 1–2 (Figure 28)

Type species: *Mahafalytenus tsilo* Silva-Dávila, sp. nov.

Etymology.— The generic name is an arbitrary combination of Mahafaly and *Ctenus*. The former honors the Mahafaly people. This tribe, well known for its wisdom and funerary art, inhabits south to southwestern Madagascar. Gender masculine.

Diagnosis.— Males and females are recognized by having a well marked, dorsal abdominal folium (Figs. 1A–B) and a palpal tarsus-tibia with long, prolateral bristles (Fig. 3C). Males differ from other ctenids by having a palpal tibia with three retrolateral processes (Figs. 10C, 11C, 13F, 14D); a conductor projecting upwards, base expanding into a lightly sclerotized lamella (Figs. 10A, 11A, 12A, 13A, 14A–B); a slender tegular process arising closer to median apophysis base (Figs. 10B, 11B, 12A, 13A, 14B); and a flagelliform embolus, arising from retrolateral side of tegulum (Figs. 10A, 11A, 12B). Females are diagnosed by having a lightly sclerotized, often translucent epigynum (Fig. 8A); median and lateral epigynal folds often well differentiated (Figs. 8A, 8C, 9A, 9C); vulva with copulatory ducts convoluted and broad; and a tripartite spermatheca, with very small head, short to medium-sized stalk, and a big base (Figs. 8B, 8D, 9B, 9D).

Description.— Medium to-large-sized spiders, total length 7.7–15.9 mm. Slight sexual dimorphism (Figs. 1 A–B). Carapace (Figs. 1A–B, 2A) longer than wide, ranging in length from 4.2–7.2 (♀♀) and 3.6–6.6 (♂♂). Fovea longitudinal and narrow. Carapace with an almost straight profile, pars thoracica as high as pars cephalica. Carapace light orange brown with two dark brown bands, covered with white, feathery hairs (Fig. 2B). Eyes arranged in a 2:4:2 pattern; PME and PLE with grate-shaped tapetum (Fig. 2C). Clypeus ranging from 0.18 to 0.52 mm. Chilum with two setose sclerotized plates (Fig. 2D). Chelicerae geniculate, with large boss (Fig. 2D); cheliceral fur-

row with three promarginal and two retromarginal teeth (Figs. 2E, 3A). Endites about two times labium length, often parallel, sometimes converging slightly (Fig. 2E). Serrula in a single row, slightly subapical (Fig. 3B). Labium wider than long, shallowly notched (Fig. 2E). Sternum wider than long, hardly extending to coxae IV (Fig. 2E).

Female palp with long prolateral bristles beneath tibia-tarsus (Fig. 3C) and pectinate claw (Fig. 3D). Legs moderately long, covered with feathery hairs (Figs. 4C–D); femur IV length 4.9–8.4 (♀♀), 5.3–8.1 (♂♂). Leg formula 4123 or 4321. Preening combs absent. Leg scopulae dense beneath tarsi-metatarsi I–II (Figs. 4A–B), sparse to absent towards metatarsi IV; tarsal- metatarsal scopula split by one or two rows of spinules (Figs. 3E–F). Two tarsal claws, with one tooth and two denticles (Fig. 4B); claw tufts dense (Figs. 4A–B). Tibiae I and II with 3 paired ventral spines, metatarsi I and II often with two paired ventral spines, sometimes only one pair; other spines vary even when comparing legs in a single specimen. Spination (based on *M. tsilo*, types), an (m) indicates the spine is missing in the opposite leg: Male: palpal femur d0-1-2, p0-0-1, r0-0-1; patella d1-0, tibia p2-1-0, r1-0-0; femur I d1-0-1-1, p0-0-0-1, r1-1-1-1; II d1-0-1-1, p1-0-1-1, r1-1-1-1; III d1-0-1-1, p1-1-1-1, r1-1-1-1; IV d1-0-1-1, p1-1-0-1, r0-1-1-1; patella with no spines; tibiae I-II d0-0-0-1-0, p0-1-0-1-0, r0-1-0-1-0, v2-0-2-0-2; tibiae III-IV d0-1-0-1-0, p0-1-0-1-0, r0-1-0-1-0, v2-0-2-0-2; metatarsi I-II p0-0-0-1; r0-0-0-1, v0-0-2-0; metatarsi III-IV p0-1-0-1-1, r0-1-0-1-1, v2-0-2-0-1. Female: palpal femur d0-1-2, p0-0-1, r0-0-1; patella d1-1-0, tibia d1-0-1, p2-1-0, r1-1-0, tarsus d1-0-0, p2-1-0, r1-1-0; femur I d0-1-0-1-1, p0-0-0-1-1, r0-1-0-1-1; II d0-1-0-1-1, p0-1-0-1-1, r0-1-0-1-1; III d0-1-0-1-1, p0-1-0-1-1, r0-1-1-1-1; IV d0-1-0-1-1, p0-1-1-1-1, r0-1-1-1-1; patella lacking spines; tibiae I-II p0-1-0-1-0, r0-0 (1 in other specimens)-0-1 (m)-0, v2-0-2-0-2; III-IV d0-1-0-1-0, p0-1-0-1-0, r0-1-0-1-0, v2-0-2-0-2; metatarsi I-II p 1-0-0-0, r1 (m)-0-0-0, v2-0-0-0; metatarsi III d0-0-1-0-0, p1-0-1-0-1, r1-0-1-0-1, v2-0-2-0-1; metatarsi IV p1-0-1-0-2, r1-0-1-0-2, v2-0-2-0-1. Tarsal trichobothria set in three to four rows, dorsal plate with three to four transverse ridges (Figs. 4C–D). Tarsal organ capsulate (Figs. 4E, 14C), aperture either oval, round, or key-shaped.

Abdomen (Figs. 1A–B, 5A) oval-shaped, longer than wide, ranging in length from 5.2–9.8 (♀♀) and 4.0–6.6 (♂♂); covered with feathery hairs (Fig. 5B); pale yellow to light brown, with two grayish bands delimiting dorsally a broad folium; venter pale yellow to light brown. Tracheal system consisting of two median and two lateral unbranched tubes. Colulus relatively large and hairy (Figs. 5A, 5C). Males with epiandrous spigots arranged in two lateral groups (Fig. 5D).

Spinnerets (Figs. 5A, 6A): anterior laterals (ALS) conical and long; posterior medians (PMS) roughly conical and short; posterior laterals (PLS) roughly cylindrical and long. Female ALS (Fig. 6B) with 2 major ampullate gland spigots and about 15 piriform gland spigots. PMS (Fig. 6C) with 1 minor ampullate gland spigot plus a tartipore sitting on an enlarged base, in addition to a second minor ampullate gland spigot, more than 15 aciniform gland spigots, and at least two cylindrical gland spigots. PLS (Figs. 6D–E) with more than 15 aciniforms and at least five cylindrical gland spigots. Male ALS (Fig. 7A) with 1 major ampullate gland spigot plus a nubbin and about 10 piriform gland spigots. PMS (Figs. 7B–C) with 1 minor ampullate gland spigot plus a tartipore sitting on an enlarged base, in addition to a second minor ampullate gland spigot, and about 8 aciniform gland spigots. PLS (Fig. 7D) with at least 15 aciniform gland spigots.

Epigynum hairy and lightly sclerotized, internal genitalia partly seen through cuticle (Fig. 5A, 8A); epigynal field often with small median sector (MS) and large lateral sectors (LS) (Figs. 8A, 17A), sometimes MS large and broad (Figs. 8C, 24A); copulatory openings often obscured by mating plugs. Spermathecae with very small head, slender stalk, and big base (Figs. 8B, 8D, 9D–E, 15B–C); fertilization ducts long, directed forward (Fig. 8B, 8D); copulatory ducts broad, and convoluted (Figs. 9B, 9D), loops sometimes asymmetrical (Figs. 8A–B); spermathecal head with primary pores occasionally scattered along the spermathecal stalk (Fig. 9F).

Male palpal tibia (Figs. 10A, 10C, 11A, 11C, 12B, 13F, 14D) with three retrolateral processes: a broad, apical RTA; a small, subapical ventrolateral process (VLTP); and a strongly sclerotized, either subapical or distal, retrodorsal process (RDTP). Cymbium lacking spines and scopula (Figs. 10–11); cymbial retrolateral edge projecting slightly (Fig. 10A), sometimes with a shallow furrow (Fig. 12B) and about five distal trichobothria (Figs. 13D–E). Tegulum with a slender process (MaTP) tapering to apex and arising at median apophysis base (Figs. 10–14). Conductor long, extending upwards, hyaline base greatly enlarged and projecting into a thin, lightly sclerotized, serrated lamella (Figs. 10A–C, 11A, 12A, 13A, 14A–C). Median apophysis sometimes with slightly bifurcated apex (Figs. 12A, 13A, 14A), often thin and long (Fig. 11B), occasionally short (Fig. 23B). Embolus flagelliform (Fig. 12A–B), arising on retrolateral side of tegulum (Figs. 10A, 11A, 13D, 14C), embolic distal lobe fits into a subtegular socket (Fig. 12C). Subtegulum with five annelli and broad lunate plate (Figs. 12B–C). Petiole elongated (Fig. 12B).

NATURAL HISTORY.— Both males and females of most species have been found between January and March. The habitat comprises mainly lowland dry forests ranging in elevation from 30 m to 300 m, only one species is known from 850 m. Adult specimens were found at night, while searching for spiders or attracted to light traps; or caught in pitfall and malaise traps in a variety of habitats; one specimen was found while beating vegetation during the day. Representatives of this genus are found in various types of vegetation including spiny forests, deciduous dry forests, gallery forests, and transitional forests.

COMPOSITION.— Seven species, all new to science.

DISTRIBUTION.— South to southwestern Madagascar (Maps 1–2 [Fig. 28])

Key to the Species of *Mahafalytenus*

(Males of *Mahafalytenus isalo* are still unknown)

1. Males 2
   Females 7
2. Median apophysis with bifurcate apex (Fig. 10A) 3
   Median apophysis with tapering apex (Fig. 11A) 4
3. Conductor base projecting into a very broad lamella (Figs. 20A–C), median apophysis sinuous in shape (Fig. 20A) . . . . . *hafa*
   Conductor base projecting into narrow lamella (Figs. 27A–D); median apophysis slightly curved (Fig. 27B) . . . . . *tsilo*
4. Median apophysis long and curved (as in Fig. 16B) 5
   Median apophysis short and nearly straight (Figs. 25 A–D) . . . . . *paosy*
5. Tibia retrodorsal process subapical (as in Fig 16C) 6
   Tibia retrodorsal process subbasal (Fig. 18C) . . . . . *folhy*
6. Apex of conductor nearly straight, lamella narrowing at base (Fig. 16D); median apophysis with smooth distal twist (Figs. 16A–B) . . . . . *fo*
   Apex of conductor ending in a short beak, lamella not so narrow at base (Fig. 25D); median apophysis with sharp distal twist (Figs. 23A–B) . . . . . *osy*
7. Epigynal median sector as large as lateral fields (Fig. 8C) 8
   Epigynal median sector shorter than lateral fields (Figs. 8A) 10
8. Epigynal median sector lobe-like (Fig. 21A) . . . . . *isalo*
   Epigynal median sector not so shaped 9
9. Epigynal median sector heart-shaped and slightly concave (Fig. 15A) . . . . . *fo*
   Epigynal median sector T-shaped and slightly swollen (Fig. 22A) . . . . . osy

10. Epigynal median sector concave or flat (Figs. 17A, 19A) 11
    Epigynal median sector pendulum-like (Figs. 26A) ..... *tsilo*
11. Epigynal median sector concave (Fig. 17A, 24A) 12
    Epigynal median sector nearly flat (Fig. 19A) ..... *hafa*
12. Epigynal median sector broad, extending farther than lateral fields, with pocket-like processes leading to copulatory openings (Fig. 24A) ..... *paosy*
    Epigynal median sector not so broad, shorter than lateral fields, without pocket-like processes (Fig. 17A) ..... *fohy*

***Mahafalytenus fo* Silva-Dávila, sp. nov.**

Figures 8C–D, 11, 15–16; Map 1 (Figure 28).

Types.— Holotype (female), Paratype (male) from Réserve Spéciale de Cap Sainte Marie, 12.3 km 262° W Marovato, 25°34′54″S, 45°10′6″E, 200 m, pitfall trap in spiny forest/thicket (11–15.ii.2002; Fisher, Griswold et al.), deposited in CAS (CASENT9014199).

Etymology.— The species name is from the Malagasy word for "heart" in reference to the epigynum shape.

Diagnosis.— Females have an epigynal median sector heart-shaped and slightly concave (Fig. 15A); vulva with copulatory ducts nearly vertical before turning into a lower loop (Figs. 15B–C). Males differ from *M. fohy* in having a subapical, smaller retrodorsal tibial process (Fig. 16C); and from *M. osy* in having a conductor with straight apex (Fig. 16B), a lamella extending downwards (Fig. 16D), and a thinner, smoothly curved retrodorsal tibial process (Fig. 16C).

Female (Holotype).— Total length 12.5. Carapace 5.1 long, 3.9 wide; ocular area 0.84 long; OQA 0.76; OQP 0.80; diameter of eyes AM:AL:PM:PL, 0.32:0.22:0.38:0.42; AME-AME 0.14; AME-ALE 0.08; AME-PME 0.10; ALE-ALE 0.82; PME-PME 0.04; PLE-PLE 0.88. Clypeal height 0.28. Sternum 2.05 long, 2.15 wide; labium 0.68 long, 0.85 wide; endites 1.43 long, 0.8 wide. Femur I 1.21 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v1 pair. Leg measurements:

	I	II	III	IV	Palp
Femur	4.7	4.5	4.5	5.8	2.0
Patella	2.1	2.1	1.7	2.0	0.9
Tibia	3.9	3.9	3.6	5.0	1.15
Metatarsus	3.7	3.8	4.1	6.1	–
Tarsus	1.6	1.6	1.7	2.3	1.6
Totals	**16.0**	**15.9**	**15.6**	**21.2**	**5.65**

Epigynum heart shaped, median sector slightly concave (Fig. 15A). Vulva as in Figs. 15B–C.

Male (Paratype).— Carapace 4.6 long, 3.8 wide; ocular area 0.76 long; OQA 0.66; OQP 0.74; diameter of eyes AM:AL:PM:PL, 0.32:0.18:0.34:0.36; AME-AME 0.08; AME-ALE 0.08; AME-PME 0.08; ALE-ALE 0.72; PME-PME 0.04; PLE-PLE 0.76. Clypeal height 0.2. Sternum 1.85 long, 2.03 wide; labium 0.58 long, 0.66 wide; endites 1.28 long, 0.66 wide. Femur I 1.21 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v2 pairs. Leg measurements:

	I	II	III	IV	Palp
Femur	4.6	4.7	4.5	6	1.85
Patella	1.9	1.9	1.6	1.9	0.7
Tibia	4.5	4.4	3.9	5.2	0.6
Metatarsus	4.3	4.3	4.5	6.2	–
Tarsus	2.0	2.0	2.1	2.7	2.0
Totals	**17.3**	**17.3**	**16.6**	**22.0**	**5.15**

Palpal tibia with RTA directed upwards; retrodorsal process subapical, smoothly curved and evenly thick; ventrolateral process spear-like (Figs. 11C, 16C); conductor apex nearly straight (Figs. 11A–B, 16C), conductor lamella extends downwards (Figs. 11C, 16 D).

MATERIAL EXAMINED.— MADAGASCAR: **Toliara**: types above.

DISTRIBUTION.— Known from southern Madagascar (Map 1 [Fig. 28]).

***Mahafalytenus fohy* Silva-Dávila, sp. nov.**

Figures 17–18; Map 2 (Figure 28).

TYPES.— HOLOTYPE (female) from Réserve Spéciale de Cap Sainte Marie, 12.3 km 262° W Marovato, 25°34′54″S, 45°10′6″E, 200 m, at light in spiny forest thicket (11–15 Feb 2002, Fisher, Griswold et al.), deposited in CAS (CASENT9012624); PARATYPE (male) from Mahafaly Plateau, 10.5 km SE Itampolo (village), 24°44.2′S, 44°1.79′E, 120 m, in disturbed spiny bush (20.ii.2005; S.M. Goodman and V. Soarimalala), deposited in CAS (CASENT9021948).

ETYMOLOGY.— The species name is from the Malagasy word for "short" in reference to the epigynal median sector.

DIAGNOSIS.— Females have an epigynal median sector shorter than lateral fields (Fig. 17A); vulva with copulatory ducts virtually forming two parallel bars before turning in a lower loop (Figs. 17B–C). Males differ from *M. fo* and *M. osy* in having a retrodorsal tibial process subbasal and larger (Fig. 18C).

FEMALE (HOLOTYPE).— Total length 10.6. Carapace 4.48 long, 3.68 wide; ocular area 0.68 long; OQA 0.72; OQP 0.66; diameter of eyes AM:AL:PM:PL, 0.18:0.2:0.32:0.36; AME-AME 0.14; AME-ALE 0.1; AME-PME 0.08; ALE-ALE 0.7; PME-PME 0.08; PLE-PLE 0.8. Clypeal height 0.28. Sternum 1.90 long, 2.09 wide; labium 0.6 long, 0.82 wide; endites 1.32 long, 0.74 wide. Femur I 1.06 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v1 pair. Leg measurements:

	I	II	III	IV	Palp
Femur	3.9	3.9	3.8	4.9	1.8
Patella	1.8	1.8	1.5	1.6	0.96
Tibia	3.1	3.1	2.8	4.0	1.04
Metatarsus	2.9	2.9	3.4	4.6	–
Tarsus	1.6	1.6	1.7	2.1	1.56
Totals	**13.3**	**13.3**	**13.2**	**17.2**	**5.36**

Epigynum with median sector shorter than lateral fields (Fig. 17A), concave and often obscured by mating plugs hard to remove. Vulva as in Figs. 17B–C.

MALE (PARATYPE).— Total length 7.9. Carapace 3.95 long, 3.4 wide; ocular area 0.70 long; OQA 0.62; OQP 0.72; diameter of eyes AM:AL:PM:PL, 0.26:0.18:0.36:0.36; AME-AME 0.08; AME-ALE 0.08; AME-PME 0.08; ALE-ALE 0.70; PME-PME 0.02; PLE-PLE 0.70. Clypeal height 0.2. Sternum 1.8 long, 1.92 wide; labium 0.48 long, 0.66 wide; endites 1.1 long, 0.54 wide. Femur I 1.32 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v2 pairs. Leg measurements:

	I	II	III	IV	Palp
Femur	4.5	4.4	4.3	5.6	1.5
Patella	1.8	1.8	1.5	1.6	0.73
Tibia	4.4	4.2	3.7	4.9	0.83
Metatarsus	4.3	4.3	4.4	6.1	–
Tarsus	2.0	2.0	2.0	2.6	1.6
Totals	**17.0**	**16.7**	**15.9**	**20.8**	**4.66**

Palpal tibia with RTA directed upwards; retrodorsal process subbasal, large; ventrolateral process with apex strongly sclerotized and slightly excavated (Fig. 18C); conductor projecting into a large lamella and tapering to a sharp apex (Figs. 18A–B); median apophysis long, slender, strongly curved (Fig. 18B).

Material examined.— Madagascar: **Toliara**: types above; Mahafaly Plateau, 6.2 km 74° ENE Itampolo, 24°39′13″S, 43°59′48″E, pitfall trap in spiny forest/thicket, 80 m, 21–25.ii.2002 (Fisher, Griswold et al., CASENT9014290), 1 ♀; Mahafaly Plateau, 6.2 km 74° ENE Itampolo, 24°39′13″S, 43°59′48″E, general spider collecting at night in spiny forest/thicket, 80 m, 21–25.ii.2002 (B.L. Fisher, et al., CASENT 9013142), 1♀.

Notes.— One female from Mahafaly Plateau with abdomen partly damaged; second female missing legs II.

Distribution .— Known from South to southwestern Madagascar (Map 2 [Fig. 28]).

***Mahafalytenus hafa* Silva-Dávila, sp. nov.**

Figures 7, 14, 19–20; Map 1 (Figure 28).

Types.— Holotype (female) plus 1 juvenile female from Parc National d'Andohahela, Forêt de Manantalinjo 33.6 km 63° ENE Amboasary, 7.6 km 99° E Hazofotsy, 6.2 km 74° ENE Itampolo, 24°49′1″S, 46°36′36″E, 150 m, collecting ground spiders in spiny forest/thicket (12–16.i.2002; Fisher, Griswold et al.), deposited in CAS (CASENT9012164); 1 ♂ paratype as above but collected in pitfall traps (CASENT 9014507).

Etymology.— The species name is from the Malagasy word for "distinct" in reference to the epigynum shape.

Diagnosis.— Females have an epigynal median sector nearly flat and square (Fig. 19A); vulva with copulatory ducts spiraling at least three times (Figs. 19B–C). Males have a conductor base projecting into a very broad lamella, a median apophysis with a slightly bifurcated apex (Figs. 14A, 20A–C), and a small retrodorsal tibial process (Figs. 14C–D, 20C).

Female (Holotype).— Total length 10.3. Carapace 4.4 long, 3.7 wide; ocular area 0.72 long; OQA 0.76; OQP 0.68; diameter of eyes AM:AL:PM:PL, 0.32:0.22:0.30:0.30; AME-AME 0.14; AME-ALE 0.06; AME-PME 0.10; ALE-ALE 0.80; PME-PME 0.06; PLE-PLE 0.86. Clypeal height 0.28. Sternum 1.8 long, 2.0 wide; labium 0.64 long, 0.9 wide; endites 1.54 long, 0.8 wide. Femur I 1.14 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v1 pair. Leg measurements:

	I	II	III	IV	Palp
Femur	4.2	3.9	3.9	5.3	1.92
Patella	1.9	1.8	1.5	1.7	0.88
Tibia	3.5	3.2	3.4	4.5	1.05
Metatarsus	3.4	3.5	4.2	5.9	–
Tarsus	1.9	1.9	2.0	2.5	1.55
Totals	**14.9**	**14.3**	**15.0**	**19.9**	**5.40**

Epigynum with median sector nearly flat and square in shape (Fig. 19A). Vulva as in Figs. 17B–C.

Male (Paratype).— Total length 7.7 (in second male). Carapace 3.55 long, 3.25 wide; ocular area 0.62 long; OQA 0.64; OQP 0.56; diameter of eyes AM:AL:PM:PL, 0.32:0.16:0.24:0.28; AME-AME 0.08; AME-ALE 0.06; AME-PME 0.08; ALE-ALE 0.64; PME-PME 0.04; PLE-PLE 0.66. Clypeal height 0.18. Sternum 1.73 long, 1.83 wide; labium 0.48 long, 0.68 wide; endites 1.1 long, 0.56 wide. Femur I 1.35 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v2 pairs. Leg measurements:

	I	II	III	IV	Palp
Femur	4.4	4.2	4.1	5.3	1.85
Patella	1.7	1.7	1.5	1.7	0.7
Tibia	0.4	3.8	3.6	4.8	0.6
Metatarsus	4.0	4.1	4.6	6.3	–
Tarsus	2.2	2.2	2.2	2.8	2.0
Totals	**16.3**	**16.0**	**16.0**	**20.9**	**5.15**

Palpal tibia with RTA directed upwards; retrodorsal process subapical, small and slightly curved; ventrolateral process digitiform, slightly curved (Figs. 14C–D, 20C); conductor basally projecting into a very broad lamella (Figs. 14A–D, 20A–C): median apophysis slightly bifurcating near apex (Figs. 14A–C).

Material examined.— Madagascar: **Toliara**: type specimens above; Andohahela Nat'l Park, Tsimelahy, Parcelle II, 24°56.21′S, 46°37.60′E, malaise trap in transitional forest, 180 m, 3–15.v.2003 (M. Irwin, F. Parker, R. Harin'Hala, CASENT9021817), 1 ♂.

Notes.— Male paratype abdomen partly damaged.

Distribution.— Known from southern Madagascar (Map 1 [Fig. 28]).

Mahafalytenus isalo Silva-Dávila, sp. nov.

Figures 2E, 21; Map 1 (Figure 28).

Types.— Holotype (female) from Parc National d'Isalo, 22°36.952′S, 45°21.26′E, 850 m, beating vegetation in daytime, gallery forest (17.i.2006; H. Wood, J. Miller), deposited in CAS (CASENT9024097, ATOL voucher MAD145).

Etymology.— The species name is a noun in apposition taken from the type locality.

Diagnosis.— This species differs from *M. tsilo* in having a large epigynal median sector with conspicuous copulatory openings (Fig. 21A); vulva with copulatory ducts forming a very broad loop (Figs. 21B–C).

Male (unknown).

Female (Holotype).— Total length 12.5. Carapace 6.3 long, 5.0 wide; ocular area 0.94 long; OQA 0.98; OQP 0.81; diameter of eyes AM:AL:PM:PL, 0.41:0.24:0.40:0.40; AME-AME 0.16; AME-ALE 0.10; AME-PME 0.13; ALE-ALE 0.98; PME-PME 0.08; PLE-PLE 1.05. Clypeal height 0.46. Sternum 2.6 long, 2.9 wide; labium 0.93 long, 1.18 wide; endites 1.93 long, 1.08 wide. Femur I 1.16 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v1 pair. Leg measurements:

	I	II	III	IV	Palp
Femur	5.8	5.7	5.6	7.3	2.8
Patella	2.2	2.5	2.3	2.5	1.44
Tibia	4.6	4.5	4.2	5.8	1.64
Metatarsus	4.5	4.5	4.9	7.1	–
Tarsus	2.3	2.3	2.5	3.1	2.28
Totals	**19.4**	**19.5**	**19.5**	**25.8**	**8.16**

Epigynum with large, lobe-like median sector (Fig. 21A). Vulva as in Figs. 21B–C.

Material examined.— Madagascar: **Fianarantsoa**: holotype above.

Distribution.— Known from south-central Madagascar (Map 1 [Fig. 28]).

***Mahafalytenus osy* Silva-Dávila, sp. nov.**

Figures 22–23; Map 2 (Figure 28).

Types.— Holotype (female) from Reserve Naturelle Integrale d'Andohahela, parcel II, 7.5 km ENE Hazofotsy, 24°49.0′S, 46°36.6′E, 120 m, camp 6 (7–15.xii.1995; S. Goodman), deposited in FMNH (CASENT 9016455); 1 ♂ paratype from Andohahela National Park, Tsimelahy, parcelle II, 24°56.21′S, 46°37.60′E, 180 m, malaise trap in transitional forest (12-11-19.xi.2002; M. Irwin, F. Parker, R. Harin'Hala), deposited in CAS (CASENT9021811).

Etymology.— The species name is from the Malagasy word for "goat" in reference to the epigynal shape.

Diagnosis.— Females have a T-shaped epigynum, with median sector slightly swollen at mid-section (Fig. 22A); vulva with copulatory ducts oblique before turning upwards into a high loop (Fig. 22B). Males differ from *M. fo* in having a conductor ending in a short beak, a lamella wider and extending mesad (Fig. 23D); a median apophysis with a sharper, distal twist (Figs. 23A–B), and a retrodorsal tibial process thicker at base (Fig. 23C). Males differ from *M. fohy* in having a smaller, subapical retrodorsal process (Fig. 23C).

Female (Holotype).— Total length 11.6. Carapace 5.7 long, 4.8 wide; ocular area 0.88 long; OQA 0.8; OQP 0.84; diameter of eyes AM:AL:PM:PL, 0.36:0.22:0.4:0.4; AME-AME 0.1; AME-ALE 0.1; AME-PME 0.13; ALE-ALE 0.9; PME-PME 0.04; PLE-PLE 0.96. Clypeal height 0.32. Sternum 2.45 long, 2.55 wide; labium 0.75 long, 0.98 wide; endites 1.73 long, 0.9 wide. Femur I 1.17 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v1 pair. Leg measurements:

	I	II	III	IV	Palp
Femur	5.6	5.5	5.3	7.1	2.1
Patella	2.4	2.4	2.1	2.2	1.15
Tibia	4.6	4.4	4.2	5.9	1.35
Metatarsus	4.3	4.5	5.0	7.1	–
Tarsus	1.9	1.9	2.1	2.6	1.85
Totals	**18.8**	**18.7**	**18.7**	**24.9**	**6.45**

Epigynum T-shaped and slightly swollen (Fig. 22A). Vulva as in Fig. 22B.

Male (Paratype).— Total length 9.5, carapace 4.6 long, 4.15 wide; ocular area 0.78 long; OQA 0.70; OQP 0.74; diameter of eyes AM:AL:PM:PL, 0.32:0.2:0.36:0.40; AME-AME 0.10; AME-ALE 0.08; AME-PME 0.08; ALE-ALE 0.76; PME-PME 0.04; PLE-PLE 0.78. Clypeal height 0.22. Sternum 2.1 long, 2.32 wide; labium 0.64 long, 0.74 wide; endites 1.4 long, 0.78 wide. Femur I 1.35 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v2 pairs. Leg measurements:

	I	II	III	IV	Palp
Femur	5.6	5.5	5.2	6.6	1.93
Patella	2.2	2.2	1.9	2.0	0.83
Tibia	5.2	5.0	4.5	5.9	1.03
Metatarsus	5.2	5.1	5.4	7.3	–
Tarsus	2.3	2.3	2.3	2.9	2.15
Totals	**20.5**	**20.1**	**19.3**	**24.7**	**5.94**

Palp with retrodorsal tibial process subapical, small, and thicker at base (Fig. 23C); conductor lamella extends mesad (Fig. 23D).

Material examined.— Madagascar: **Toliara**: types above; Parc National d' Andohahela, Forêt d'Ambohibory, 1.7 km 61° ENE Tsimielahy, 36.3 km 308° NW Tolagnaro, 24°55′48″S, 46°38′44″E, malaise trap in transitional forest, 300 m, 16–20.i.2002 (B. Fisher et al., CASENT 9012274), 1 ♂.

Distribution.—Known from southern Madagascar (Map 2 [Fig. 28]).

***Mahafalytenus paosy* Silva-Dávila, sp. nov.**

Figures 2A–D, 3A–B, 3E–F, 4A–C, 4E, 5A–C, 6D, 9, 24–25; Map 1 (Figure 28).

Types.— Holotype (female) plus 1 ♀ paratype and 3 juveniles from Mahafaly Plateau, 6.2 km 74° ENE Itampolo, 24°39′13″S, 43°59′48″E, 80 m, general spider night collecting, spiny forest/thicket (21–25.ii.2002; Fisher, Griswold et al.), deposited in CAS (CASENT9013143); 1 ♂ paratype 1 ♀ carapace from Mahafaly Plateau, 10.5 km SE Itampolo (village), 24°44.2′S, 44°1.79′E, 120 m, disturbed spiny bush (19.ii.2005; S.M. Goodman and V. Soarimalala), deposited in CAS (CASENT9021947).

Etymology.— The species name is from the Malagasy word for "pocket" in reference to the epigynal median sector.

Diagnosis.— Females differ from *M. tsilo* in having a larger, broad median sector with pocket-like processes (Figs. 9C, 24A); vulva with long copulatory ducts, spermathecal heads clearly visible (Figs. 9D, 24B–C). Males differ from *M. tsilo* in having a short median apophysis tapering to apex (Fig. 25B).

Female (Holotype).— Total length 15.9. Carapace 6.5 long, 5.7 wide; ocular area 1.06 long; OQA 1.08; OQP 1.00; diameter of eyes AM:AL:PM:PL, 0.46:0.22:0.46:0.52; AME-AME 0.22; AME-ALE 0.14; AME-PME 0.14; ALE-ALE 1.10; PME-PME 0.12; PLE-PLE 1.28. Clypeal height 0.46. Sternum 2.75 long, 3.05 wide; labium 1.1 long, 1.3 wide; endites 2.25 long, 1.1 wide. Femur I 1.16 times carapace width. Spination: tibiae I-II v3 pairs, metatarsus I v 1 pair+1, metatarsus II v2 pairs (met I v 1 pair/met II v 1 pair+1, in other females). Leg measurements:

	I	II	III	IV	Palp
Femur	6.6	6.3	6.3	7.9	2.85
Patella	2.5	2.4	2.4	2.5	1.4
Tibia	5.2	5.1	4.9	6.6	1.8
Metatarsus	4.9	5.1	5.8	7.8	–
Tarsus	2.3	2.3	2.8	3.3	2.45
Totals	**21.5**	**21.2**	**22.2**	**28.1**	**8.50**

Epigynal median sector broad, with pocket-like processes (Figs. 9A, 24A). Vulva as in Figs. 9D, 24B–C.

Male (Paratype).— Total length 12.51. Carapace 6.6 long, 5.6 wide; ocular area 1.08 long; OQA 1.08; OQP 0.98; diameter of eyes AM:AL:PM:PL, 0.44:0.28:0.44:0.52; AME-AME 0.24; AME-ALE 0.08; AME-PME 0.10; ALE-ALE 1.04; PME-PME 0.08; PLE-PLE 1.22. Clypeal height 0.58. Sternum 2.65 long, 3.15 wide; labium 1.13 long, 1.25 wide; endites 2.08 long, 1.13 wide. Femur I 1.18 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v2 pairs. Leg measurements:

	I	II	III	IV	Palp
Femur	6.6	6.6	6.3	8.1	3.3
Patella	2.6	2.5	2.3	2.5	1.0
Tibia	5.6	5.5	5.6	7.0	1.4
Metatarsus	5.9	5.6	6.4	8.4	–
Tarsus	3.0	2.9	3.2	3.7	3.0
Totals	**23.7**	**23.1**	**23.8**	**29.7**	**8.7**

Palpal cymbium with shallow retrolateral furrow (Fig. 25C); RTA projecting upwards; retrodorsal tibial process subapical, small, thick, and curved; ventrolateral process lightly sclerotized, short and thick (Figs. 25A, C); conductor projecting into a narrow lamella; median apophysis short and slender (Figs. 25A–D).

Material examined.— Madagascar: **Toliara**: type specimens above; Mahafaly Plateau, 10.5 km SE Itampolo (village), 24°44.2′S, 44°1.79′E, 120 m, disturbed spiny bush, 20.ii.2005 (S.M. Goodman and V.

Soarimalala, CASENT 9021973), 1 ♀; Parc Nat. de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81° E Efoetse, 23.0 km 131° SE Beheloka, 23°59′32″S, 43°52′50″E, 90 m, general spider collecting at night, 22–26.ii.2002, spiny forest/thicket (B.L. Fisher, et al., CASENT9014084), 2 ♀.

Distribution.— Known from southwestern Madagascar (Map 1 [Fig. 28]).

***Mahafalytenus tsilo* Silva-Dávila, sp. nov.**

Figures 1–6, 8–10, 12–13, 26–27; Map 2 (Figure 28).

Types.— Holotype (female), Paratype (male) from Forêt de Tsinjoriaky, 6.2 km 84° E Tsifota, 22°48′8″S, 043°25′14″E, 70 m, general spider night collecting (6–10.iii.2002; B.L. Fisher et al.), deposited in CAS (CASENT9013016).

Etymology.— The species name is from the Malagasy for "thorn" in reference to the anterior edge of the epigynal median sector.

Diagnosis.— Females have a small, pendulum-like epigynal median sector (Figs. 8A, 9A, 26A); vulva with copulatory ducts nearly obscuring spermathecal heads and sometimes asymmetrical (Figs. 8B, 9B, 26B). Males have a tegular conductor projecting into a narrow lamella and a median apophysis with a bifurcated apex (Figs. 10A–C, 12A, 13A, 27A–D).

Female (Holotype).— Total length 14.13. Carapace 6.7 long, 5.9 wide; ocular area 1.02 long; OQA 0.98; OQP 0.92; diameter of eyes AM:AL:PM:PL, 0.42:0.26:0.42:0.52; AME-AME 0.20; AME-ALE 0.10; AME-PME 0.16; ALE-ALE 1.00; PME-PME 0.08; PLE-PLE 1.20. Clypeal height 0.46. Sternum 2.95 long, 3.15 wide; labium 1.08 long, 1.25 wide; endites 2.2 long, 1.13 wide. Femur I 1.10 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v1 pair. Leg measurements:

	I	II	III	IV	Palp
Femur	6.5	6.5	6.5	8.3	3.0
Patella	2.6	2.7	2.5	2.5	1.5
Tibia	5.2	5.3	5.2	6.7	1.85
Metatarsus	4.9	4.9	5.7	7.5	–
Tarsus	2.5	2.6	2.9	3.5	2.65
Totals	**21.7**	**22.0**	**22.8**	**28.5**	**9.00**

Epigynum with small, pendulum-like median sector (Figs. 8A, 9A, 26A). Vulva as in Figs. 8B, 9B, 26B–C.

Male (Paratype).— Total length 9.3. Carapace 4.7 long, 3.95 wide; ocular area 0.74 long; OQA 0.78; OQP 0.74; diameter of eyes AM:AL:PM:PL, 0.34:0.02:0.34:0.34; AME-AME 0.14; AME-ALE 0.02; AME-PME 0.08; ALE-ALE 0.74; PME-PME 0.04; PLE-PLE 0.90. Clypeal height 0.24. Sternum 2.2 long, 2.25 wide; labium 0.73 long, 0.88 wide; endites 1.48 long, 0.75 wide. Femur I 1.3 times carapace width. Spination: tibiae I-II v3 pairs, metatarsi I-II v2 pairs. Leg measurements:

	I	II	III	IV	Palp
Femur	5.2	5.1	5.3	6.6	2.3
Patella	2.0	2.0	1.9	2.1	0.65
Tibia	4.7	4.7	4.7	5.8	1.0
Metatarsus	4.4	4.6	5.2	6.6	–
Tarsus	2.5	2.6	2.9	3.3	2.2
Totals	**18.8**	**19.1**	**20.0**	**24.4**	**6.15**

Palpal cymbium with shallow retrolateral furrow; RTA directed inwards; retrodorsal process subapical, small and pointing outwards; ventrolateral process digitiform, lightly sclerotized, long and slender (Figs. 10C, 13F); conductor projecting into a narrow lamella, apex with a blade-like

edge, partly wrapping embolus (Figs. 10A–C, 13A–C); median apophysis long, with apex strongly bifurcated (Figs. 10A, 12A, 13A, 27B).

Material examined.— Madagascar: **Toliara**: type specimens above plus 1 juvenile; Forêt de Tsinjoriaky, 6.2 km 84° E Tsifota, 22°48′8″S, 043°25′14″E, 70 m, general spider collecting at night, 6–10.iii.2002 (B.L. Fisher, et al., CASENT9018697), 5 ♀; Mikea Forest, NW of Manombo, 22°54.22′S, 43°28.53′E, 30 m, malaise trap in deciduous dry forest, 16–17.i.2002 (R. Harin'Hala, CASENT9020814), 1 ♂; Mikea Forest, NW of Manombo, 22°54.22′S, 43°28.53′E, 30 m, malaise trap in deciduous dry forest, 6–16.i.2002 (R. Harin'Hala, CASENT9010440), 1 ♀; Lake Ranobe, 100 m from lake edge, 23°2.941′S, 43°36.635′E, 30 m, spider collecting in spiny forest, 21–28.i.2003 (Frontier Wilderness Project, CASENT 9016470), 1 ♀.

Distribution.— Known from southwestern Madagascar (Map 2 [Fig. 28]).

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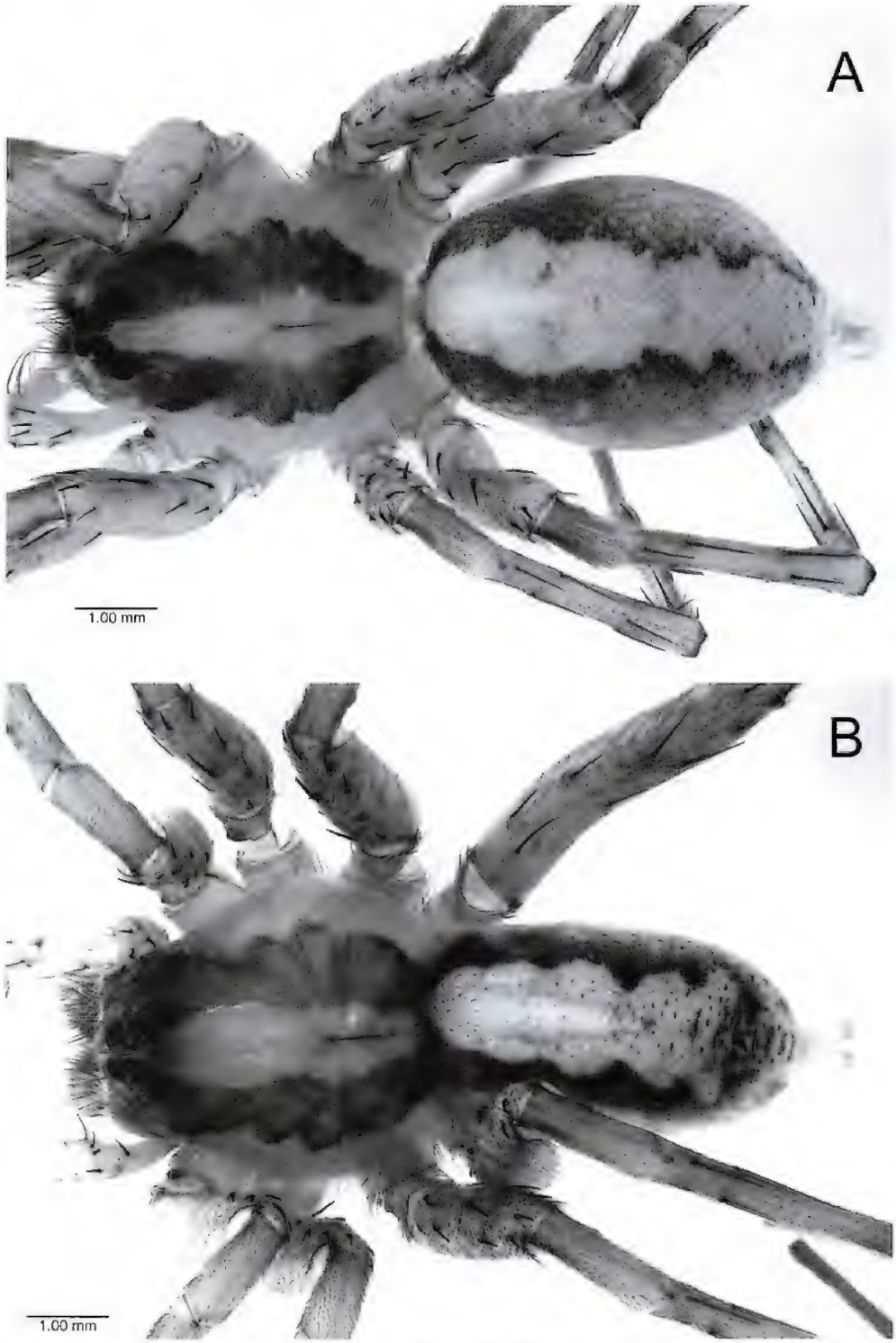

FIGURE 1. *Mahafalytenus* spp., habitus, dorsal view. A. *M. fohy*, sp. nov., female holotype, CASENT9012624. B. *M. tsilo*, sp. nov., male paratype, CASENT9013016.

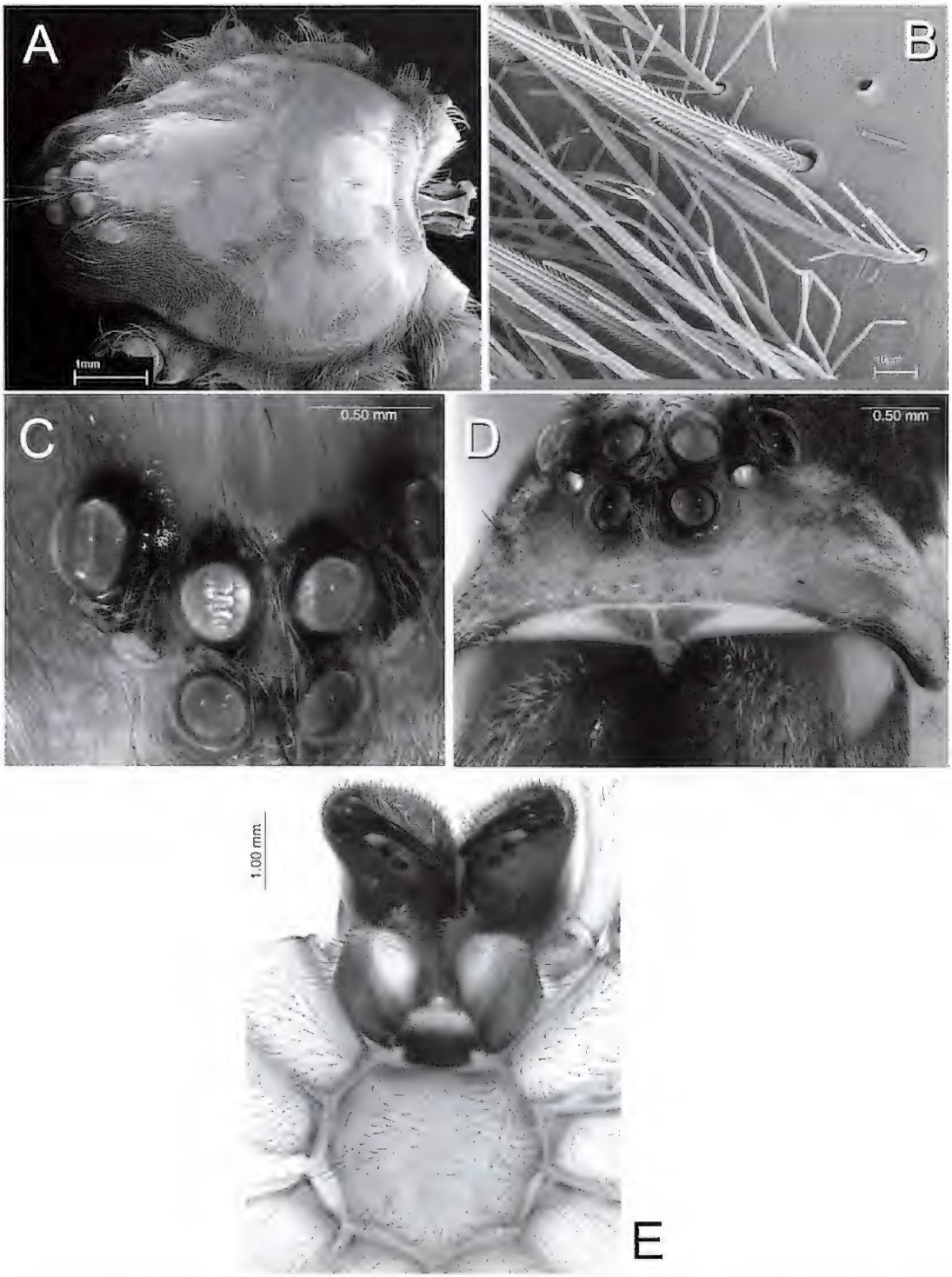

FIGURE 2. *Mahafalytenus* spp., female. A–B. *M. paosy*, sp. nov., CASENT9014084. A. Carapace, dorsal view. B. Close up of carapace hairs. C–D. *M. paosy*, sp. nov., CASENT9018697. C. Close up of PME grate-shaped tapetum. D. Carapace, frontal view. E. *M. isalo*, sp. nov., holotype, cephalothorax, ventral view.

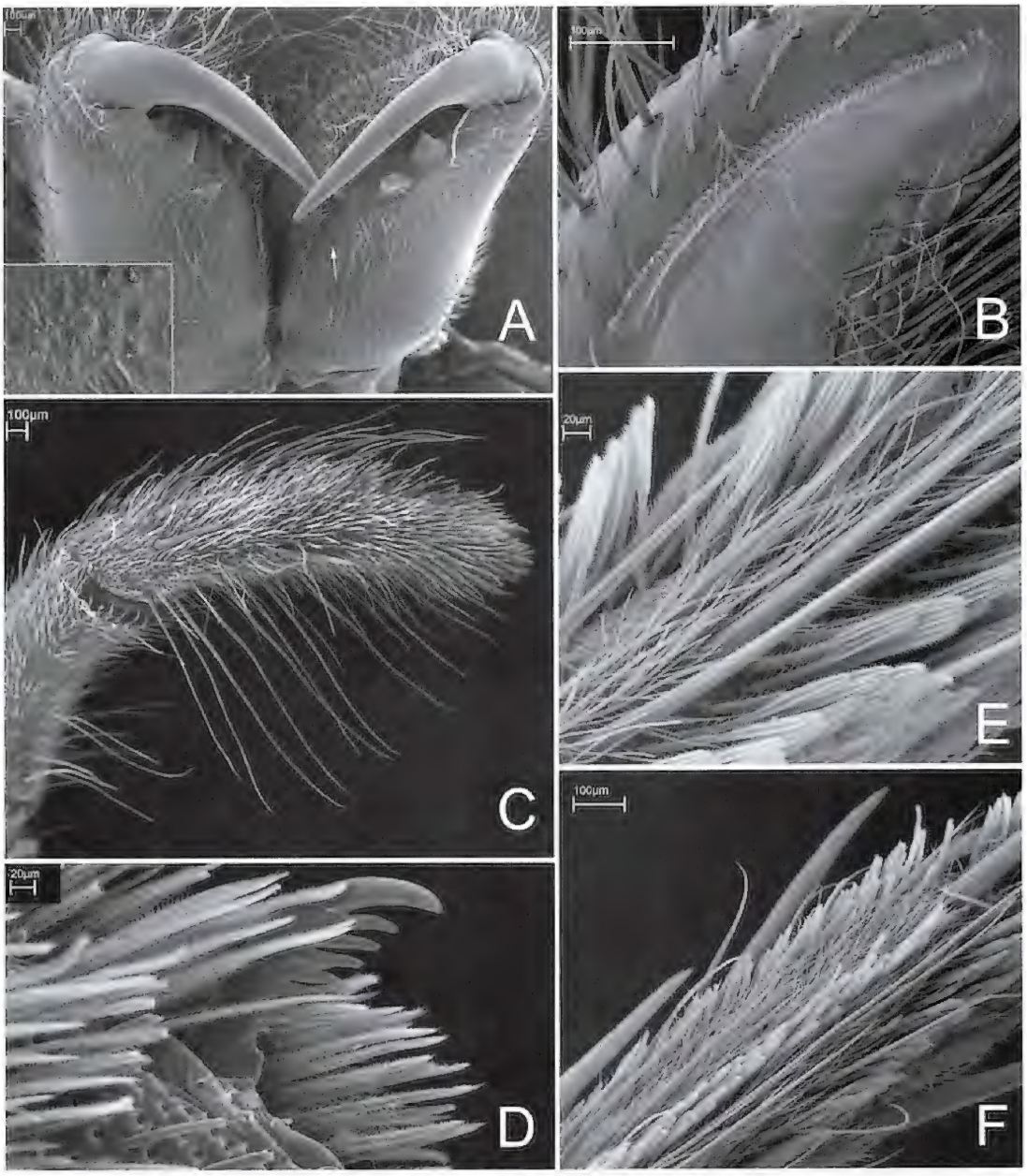

Figure 3. *Mahafalytenus* spp., female. A–B, E–F. *M. paosy*, sp. nov., CASENT9014084. A. Chelicerae; inset and arrow to cheliceral glands. B. Close up of right serrula, ventral view. C–D. *M. tsilo*, sp. nov., CASENT9018697. C. Left pedipalp, close up of tarsal setae, prolateral view. D. Left pedipalp, tarsal claw. E. Leg I, close up of tarsal scopula, ventral view. F. Leg I, close up of metatarsal scopula, ventral view.

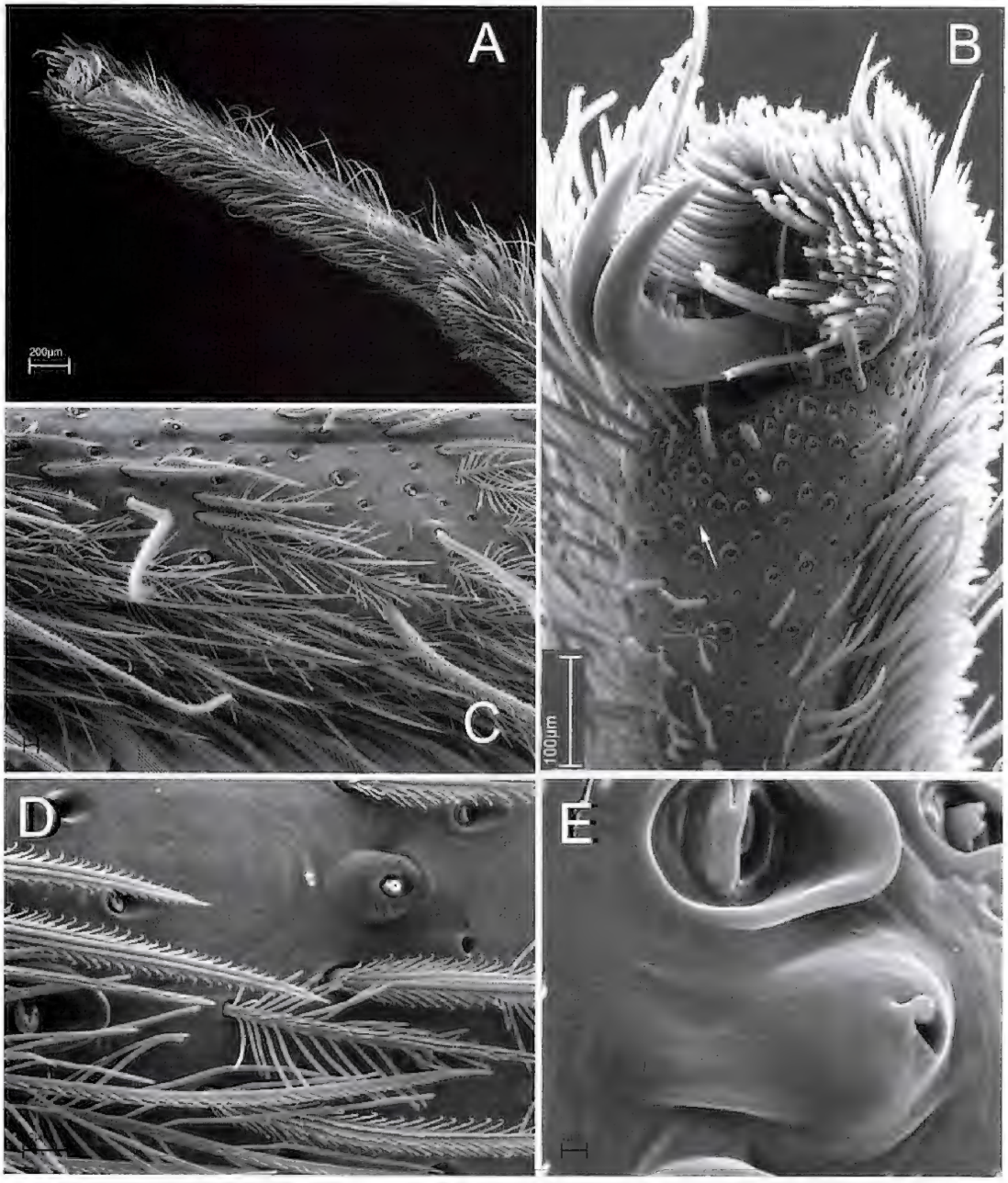

Figure 4. *Mahafalytenus* spp, female tarsi. A, C–E. *M. paosy*, CASENT9014084. A. I left tarsus, retrolateral view. B. *M. tsilo*, sp. nov., CASENT9018697; close up of I left tarsus, prolateral view, arrow to tarsal organ. C. Tarsal hairs and trichobothria. D. Close up of feathery hair and trichobothrium. E. Close up of tarsal organ.

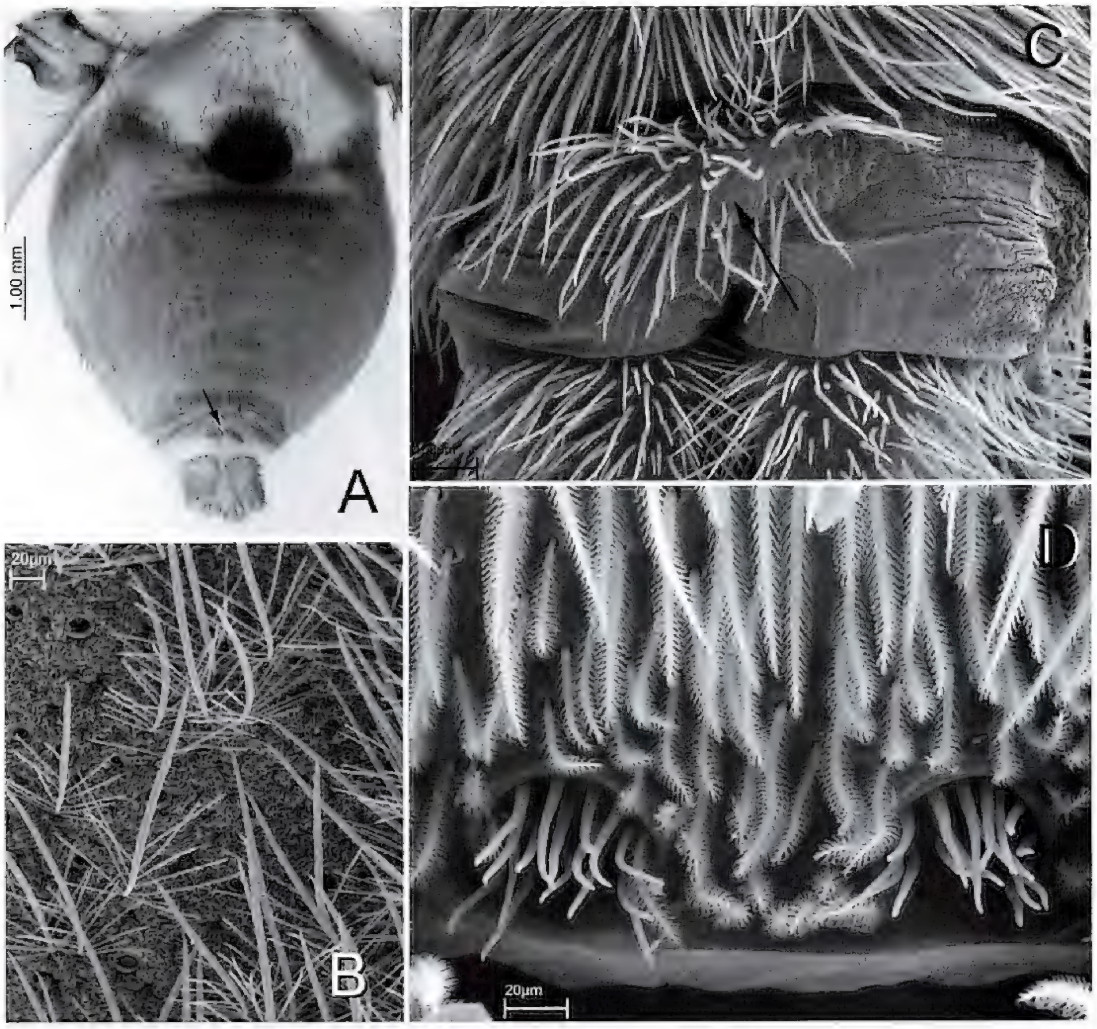

FIGURE 5. *Mahafalytenus* spp., abdomen. A–C. *M. paosy*, female CASENT9014084. A. Abdomen, ventral view, arrow to colulus. B. Close of abdominal hairs, dorsal view. C. Close up of colulus, arrow to colulus. D. *M. tsilo*, sp. nov., male CASENT9020814, close up of epiandrous gland spigots.

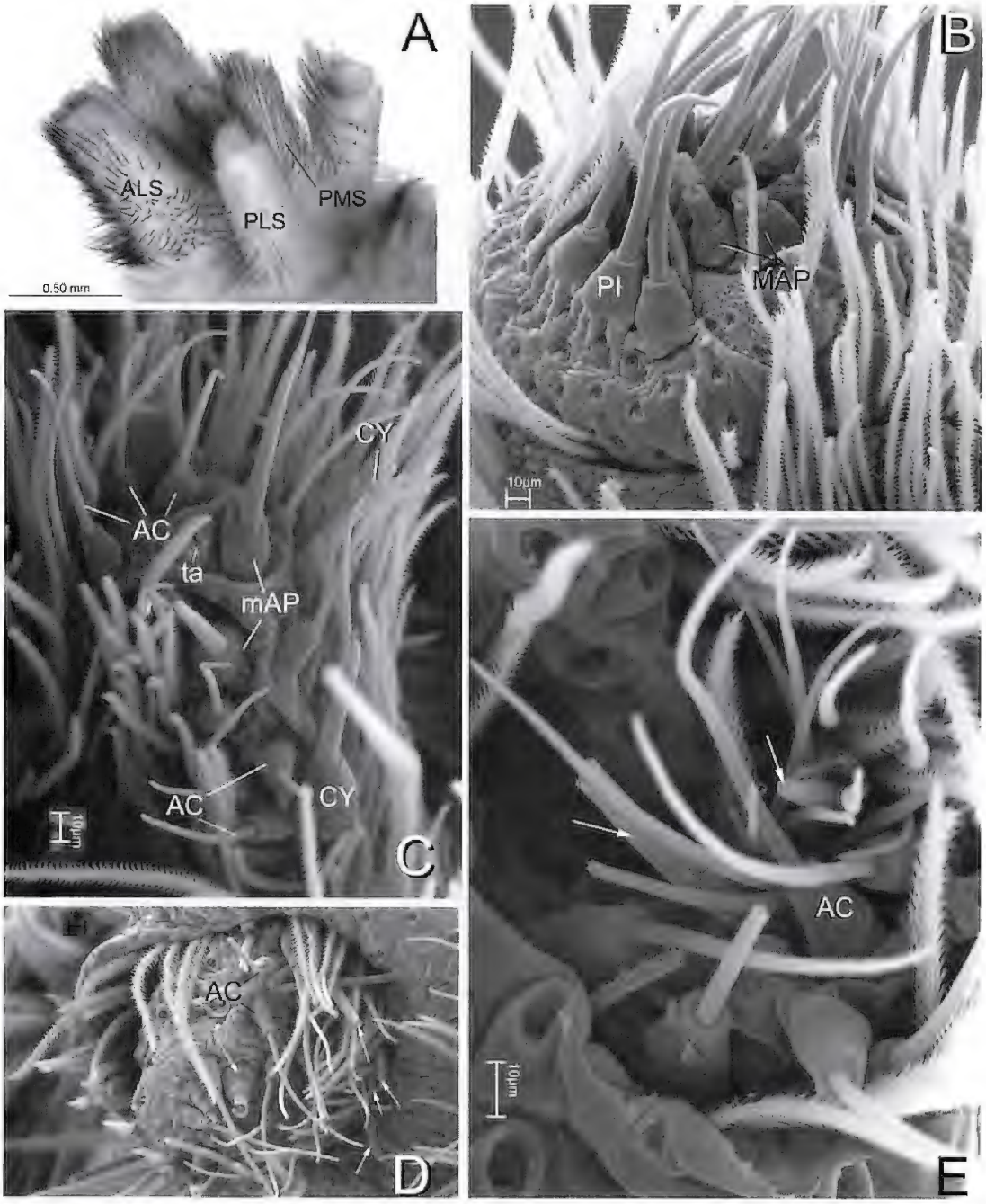

FIGURE 6. *Mahafalytenus* spp., female spinnerets. A–C, E. *M. tsilo*, sp. nov., CASENT9018697. A. Overview. B. ALS. C. PMS. D. *M. paosy*, sp. nov., CASENT9014084, PLS, arrows to CY. E. Close up of PLS, arrows to CY. AC= aciniform gland spigots, ALS= anterior lateral spinneret, CY= cylindrical gland spigots, MAP= major ampullate gland spigots, mAP= minor ampullate gland spigots, PI= piriform gland spigots, PLS= posterior lateral spinneret, PMS= posterior median spinneret, ta= tartipore.

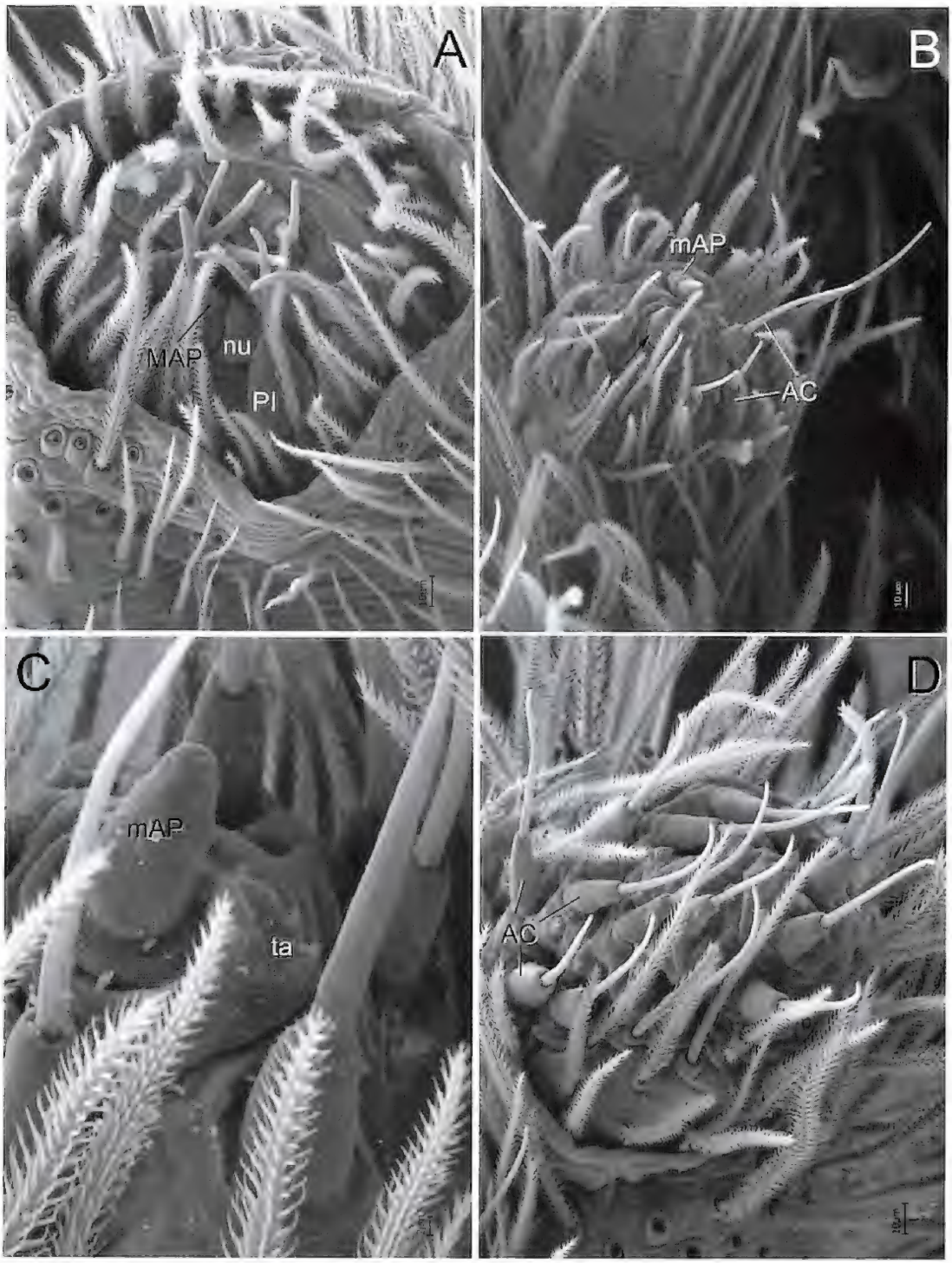

FIGURE 7. *Mahafalytenus hafa*, sp. nov., male paratype spinnerets, CASENT9014507. A. ALS. B. PMS. C. Close up of PMS. D. PLS. AC= aciniform gland spigots, MAP= major ampullate gland spigots, mAP= minor ampullate gland spigots, nu= nubbin, PI= piriform gland spigots, ta= tartipore.

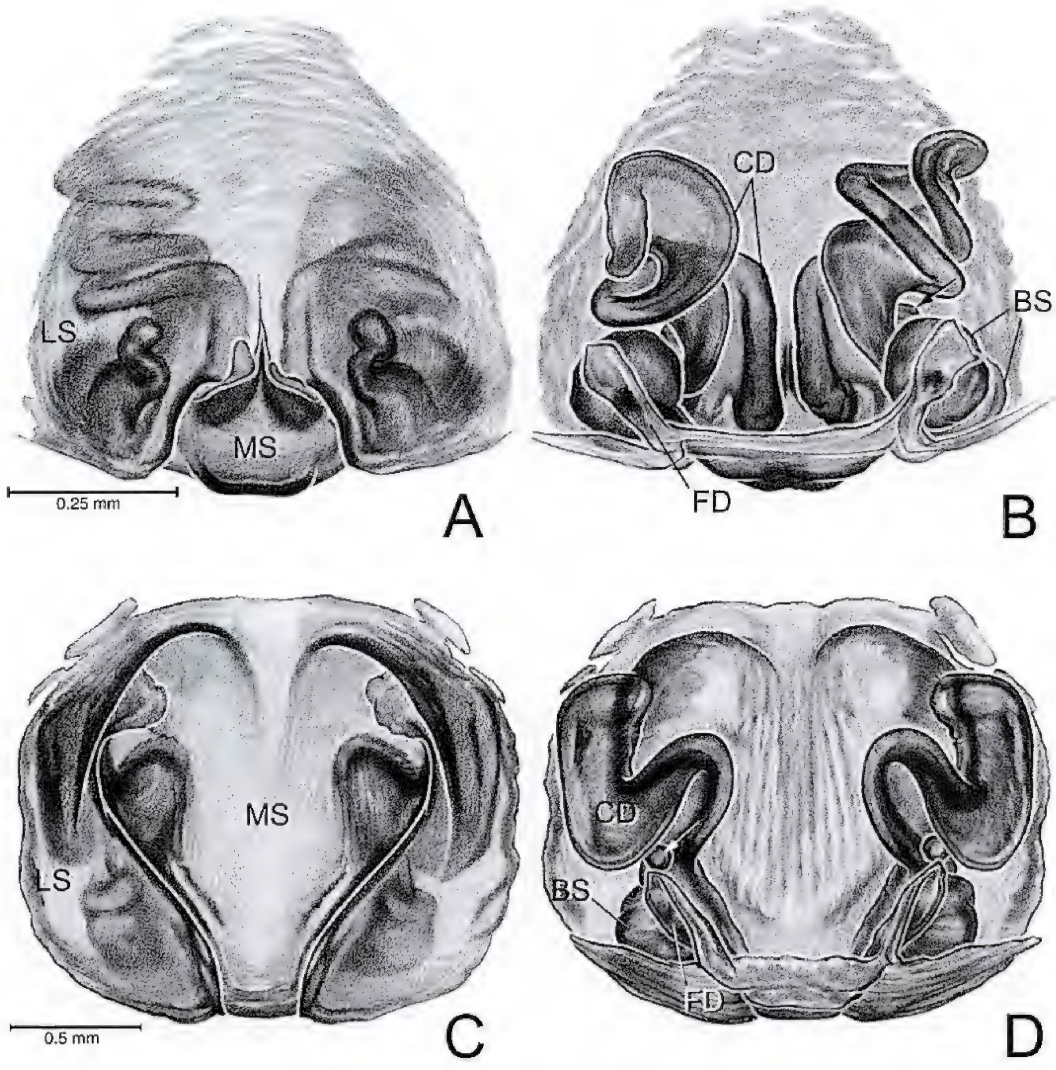

FIGURE 8. *Mahafalytenus* spp., female genitalia. A–B. *M. tsilo*, sp. nov., holotype. C–D. *M. fo*, sp. nov., holotype. A, C. Epigynum, ventral view. LS= epigynal lateral sector, MS= epigynal median sector. B, D. Vulva, dorsal view; arrow to spermathecal head. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct.

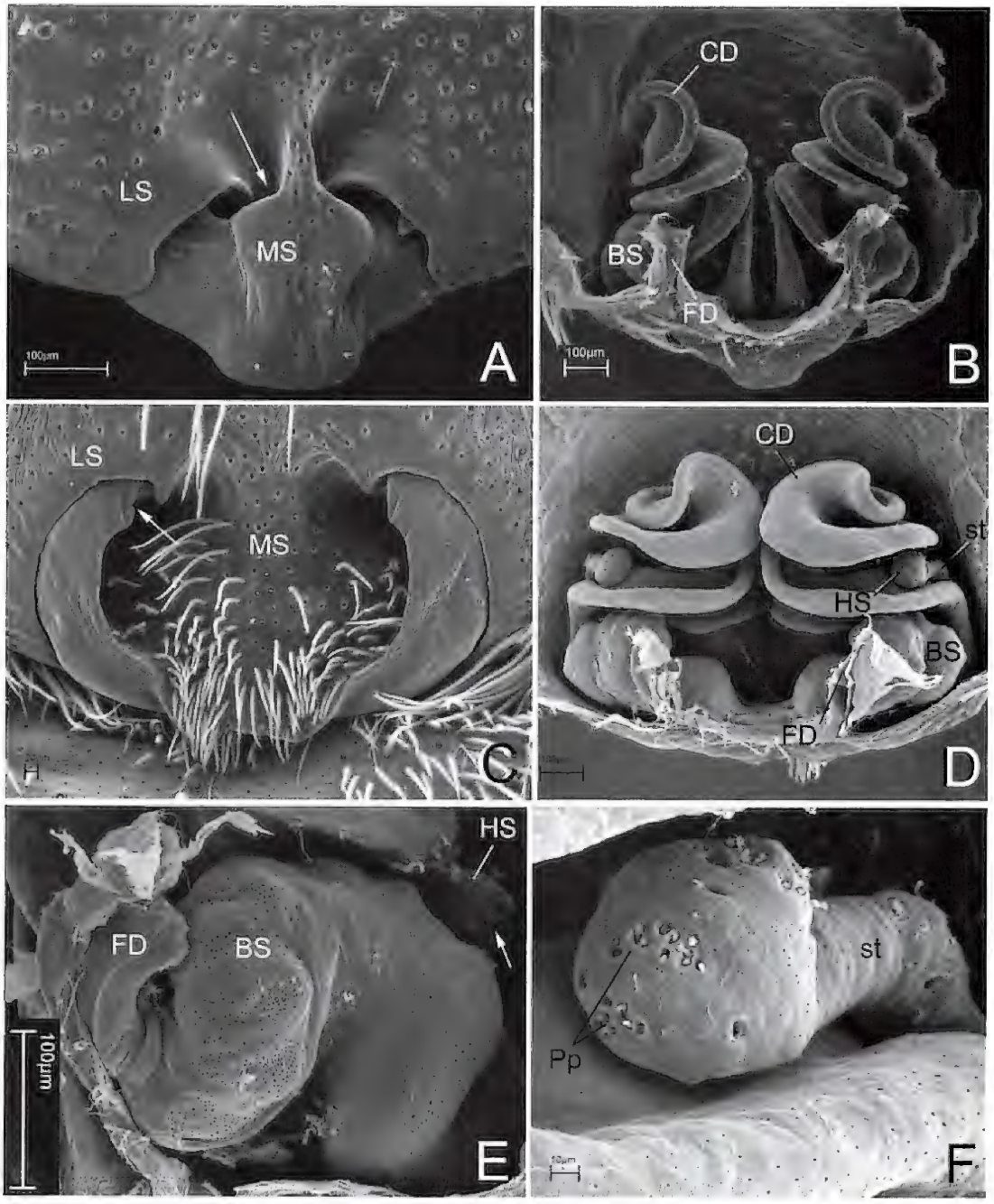

FIGURE 9. *Mahafalytenus* spp., female genitalia. A–B, E. *M. tsilo*, sp. nov., CASENT9018697. C–D, F. *M. paosy*, sp. nov., CASENT9014084. A, C. Epigynum, ventral view, arrows to copulatory opening. B, D. Vulva, dorsal view. E. Close up of left spermatheca, arrow to Pp. F. Close up of HS. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector, Pp= primary pores, st= stalk.

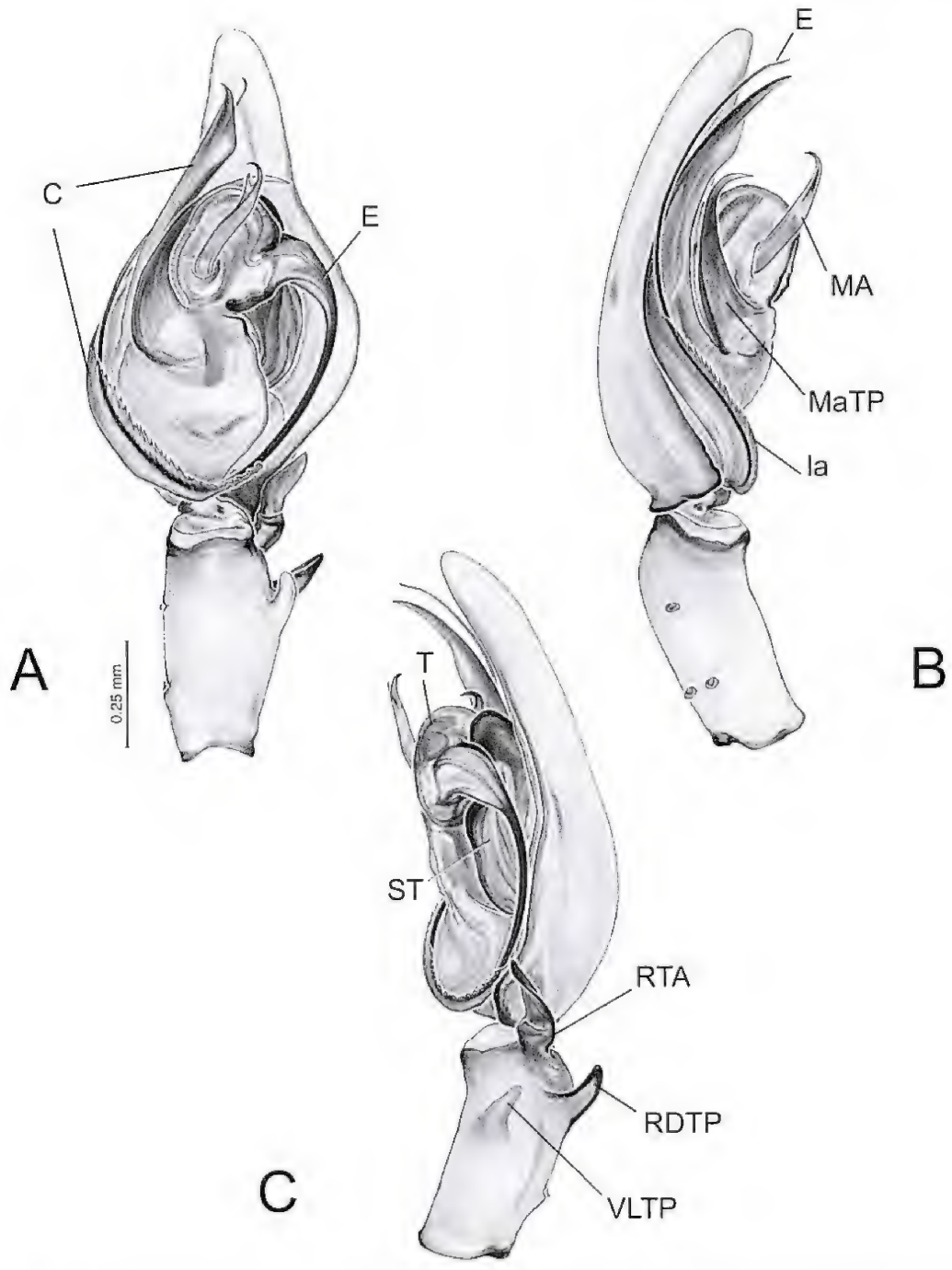

FIGURE 10. *Mahafalytenus tsilo*, sp. nov., left palp, male CASENT9013016. A. Ventral view. B. Prolateral view. C. Retrolateral view. C= conductor, E= embolus, la= lamella of conductor, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, RDTP= retro-dorsal tibial process, RTA= retrolateral tibial apophysis, ST= subtegulum, T= tegulum, VLTP= ventro-lateral tibial process

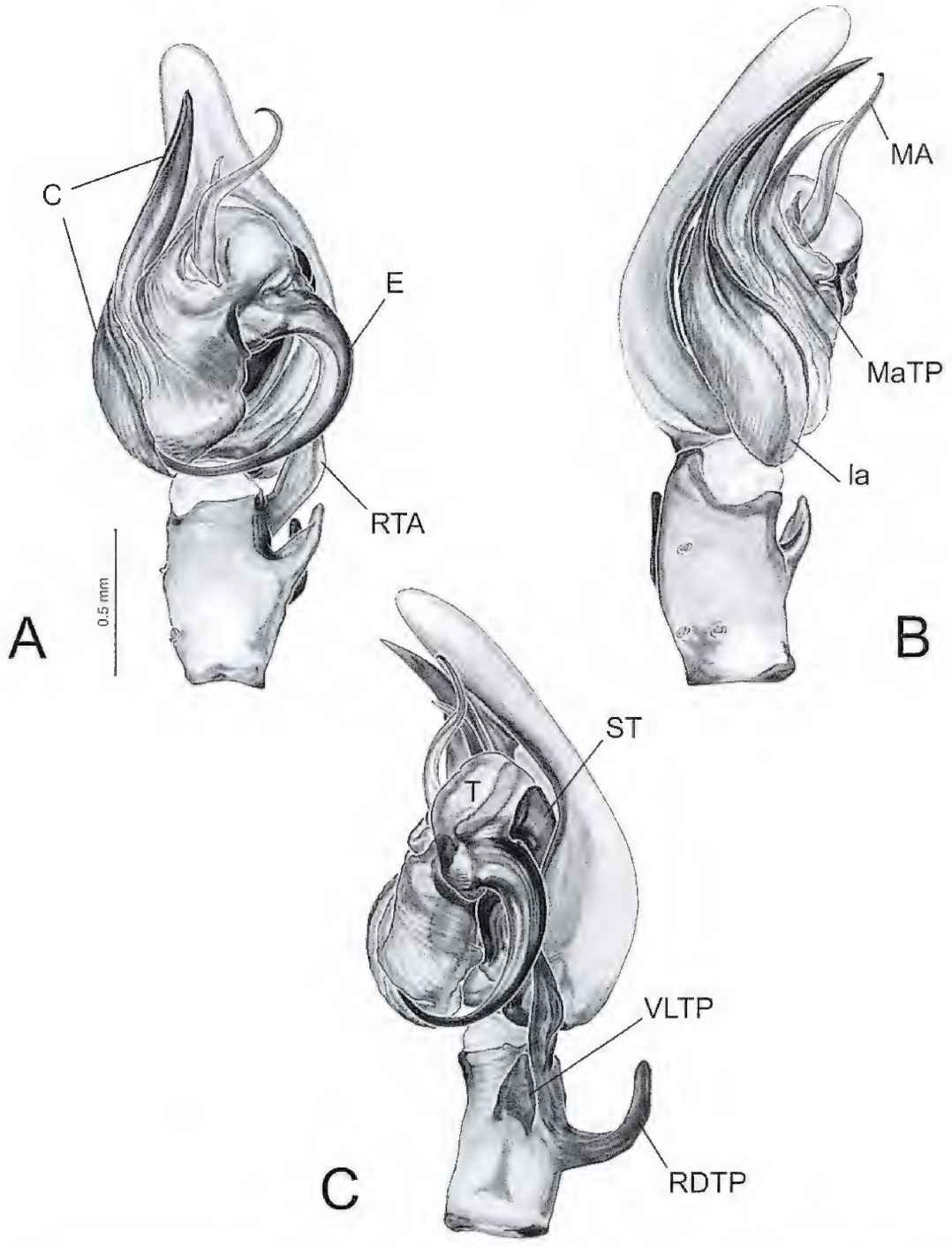

FIGURE 11. *Mahafalytenus fo*, sp. nov., left palp, male CASENT9014199. A. Ventral view. B. Prolateral view. C. Retrolateral view. C= conductor, E= embolus, la= lamella of conductor, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, RDTP= retro-dorsal tibial process, RTA= retrolateral tibial apophysis, ST= subtegulum, T= tegulum, VLTP= ventro-lateral tibial process.

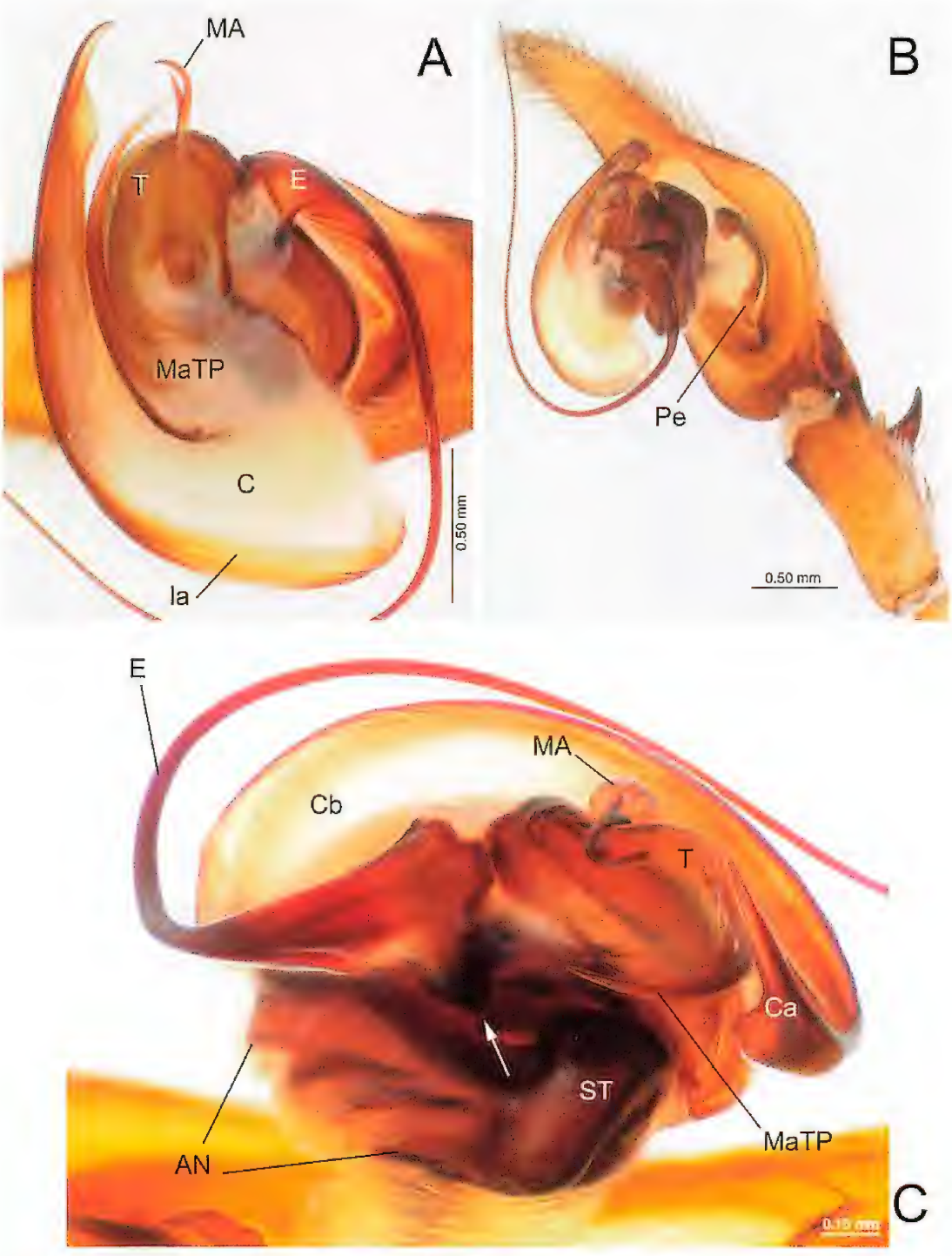

FIGURE 12. *Mahafalytenus tsilo*, sp. nov., male CASENT9020814, expanded left palp. A. Ventral view. B. Retrolateral view. C. Prolateral view, arrow to embolic lobe. AN= subtegular anelli, C= conductor, Ca= apex of conductor, Cb= base of conductor, E= embolus, la= lamella of conductor, MA= median apophysis, MaTP=*Mahafalytenus* tegular process, Pe= petiole, ST= subtegulum, T= tegulum.

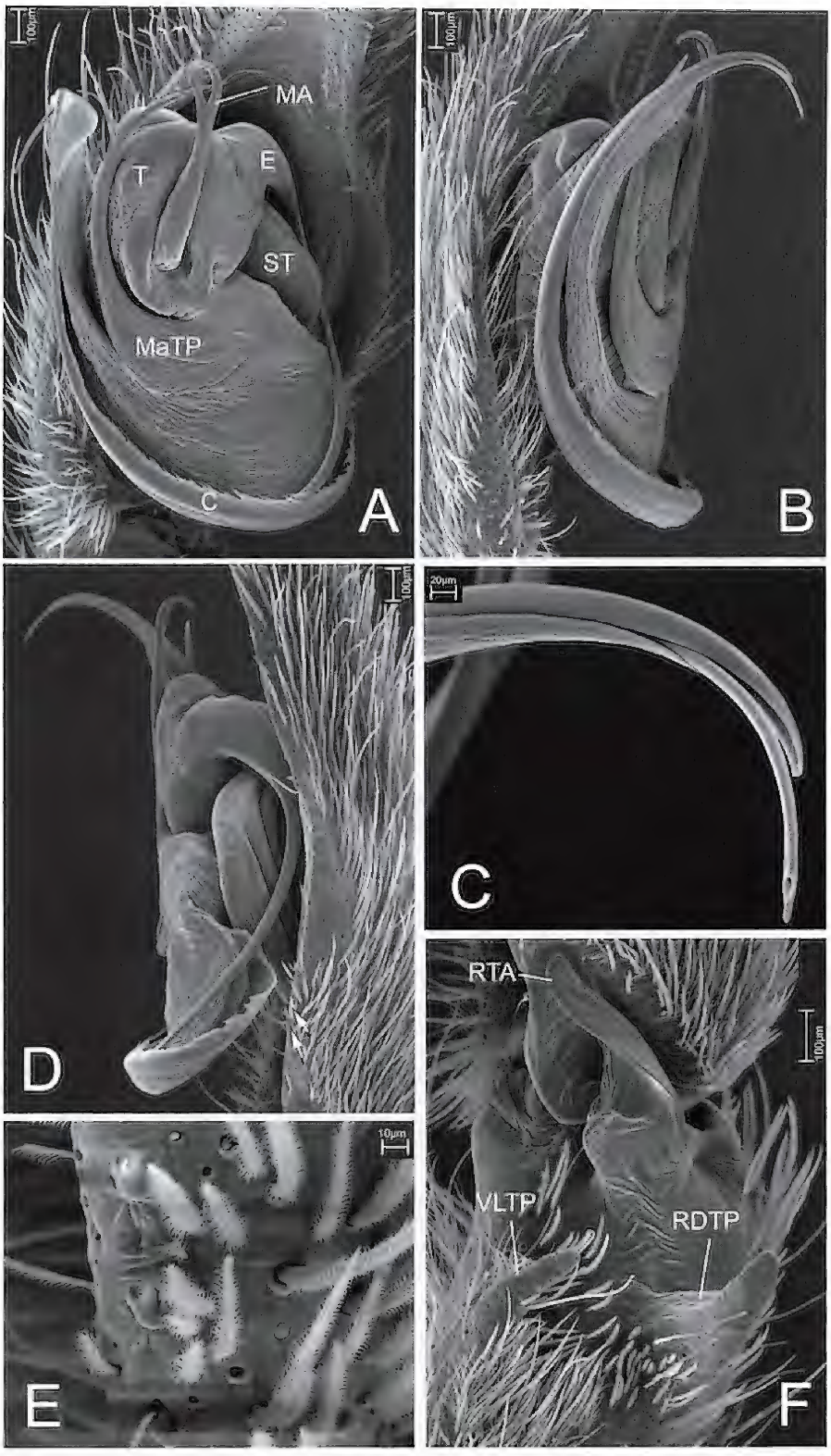

FIGURE 13. *Mahafalytenus tsilo*, sp. nov., male CASENT9020814, right palp. A.Ventral view. B. Prolateral view. C. Close up of conductor wrapping embolic tip, prolateral view. D. Retrolateral view, arrows to cymbial trichobothria. E. Cymbial base, retrolateral view. F. Tibial processes, retrolateral view. C = conductor, E = embolus, MA = median apophysis, MaTP= *Mahafalytenus* tegular process, RDTP = retrodorsal tibialprocess, RTA = retrolateral tibial apophysis, ST= subtegulum, T= tegulum, VLTP= ventrolateral tibial process.

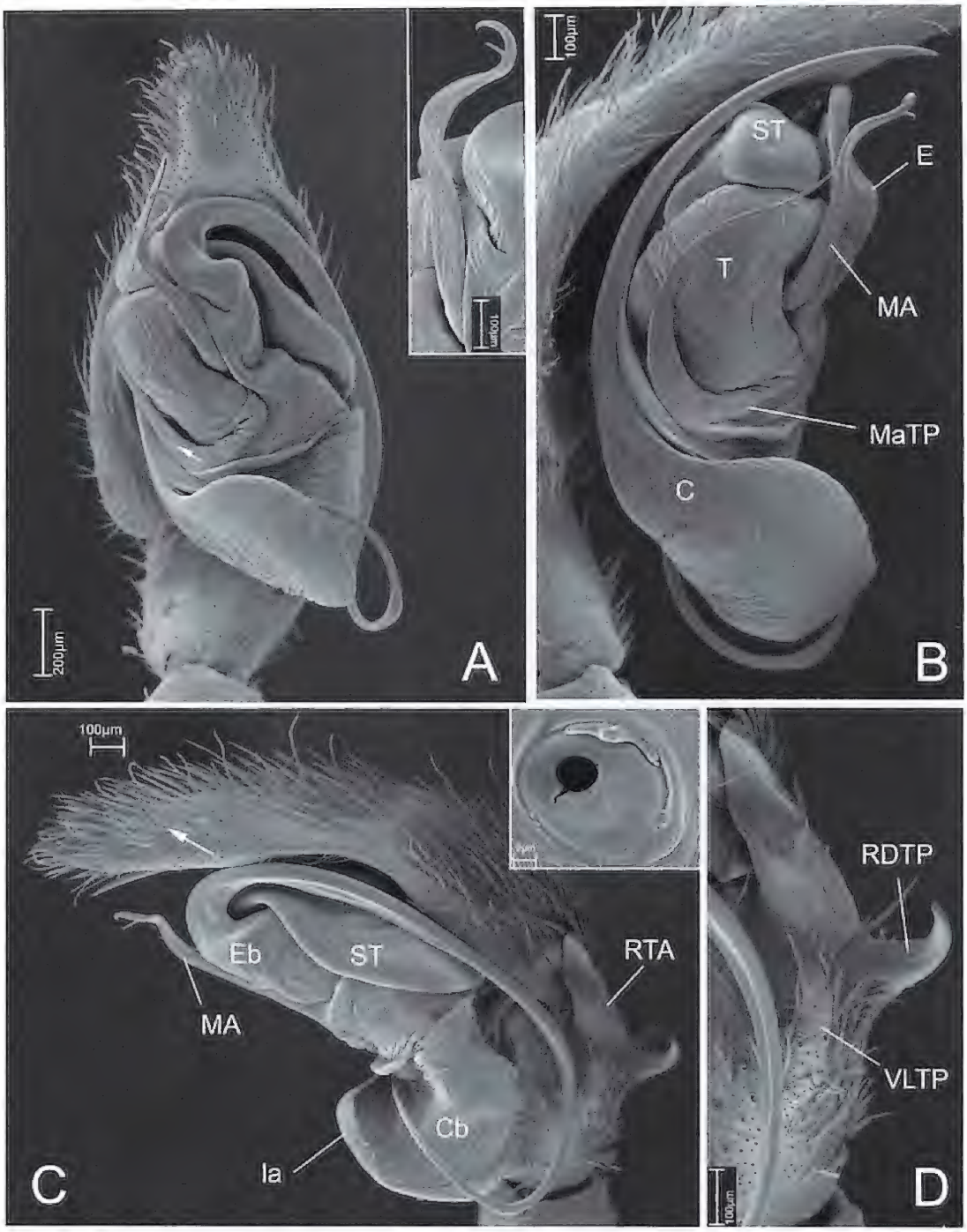

FIGURE 14. *Mahafalytenus hafa*, sp. nov., male CASENT9014507, right palp. A. Ventral view, arrow to MaTP, inset of MA. B. Prolateral view. C. Retrolateral view, inset and arrow to tarsal organ. D. Tibial processes, retrolateral view. C= conductor, Cb= base of conductor, E= embolus, Eb= embolus base, Ia= lamella of conductor, MA= median apophysis, MaTP=*Mahafalytenus* tegular process, RDTP= retro-dorsal tibial process, RTA= retrolateral tibial apophysis, ST= subtegulum, T= tegulum, VLTP= ventro-lateral tibial process.

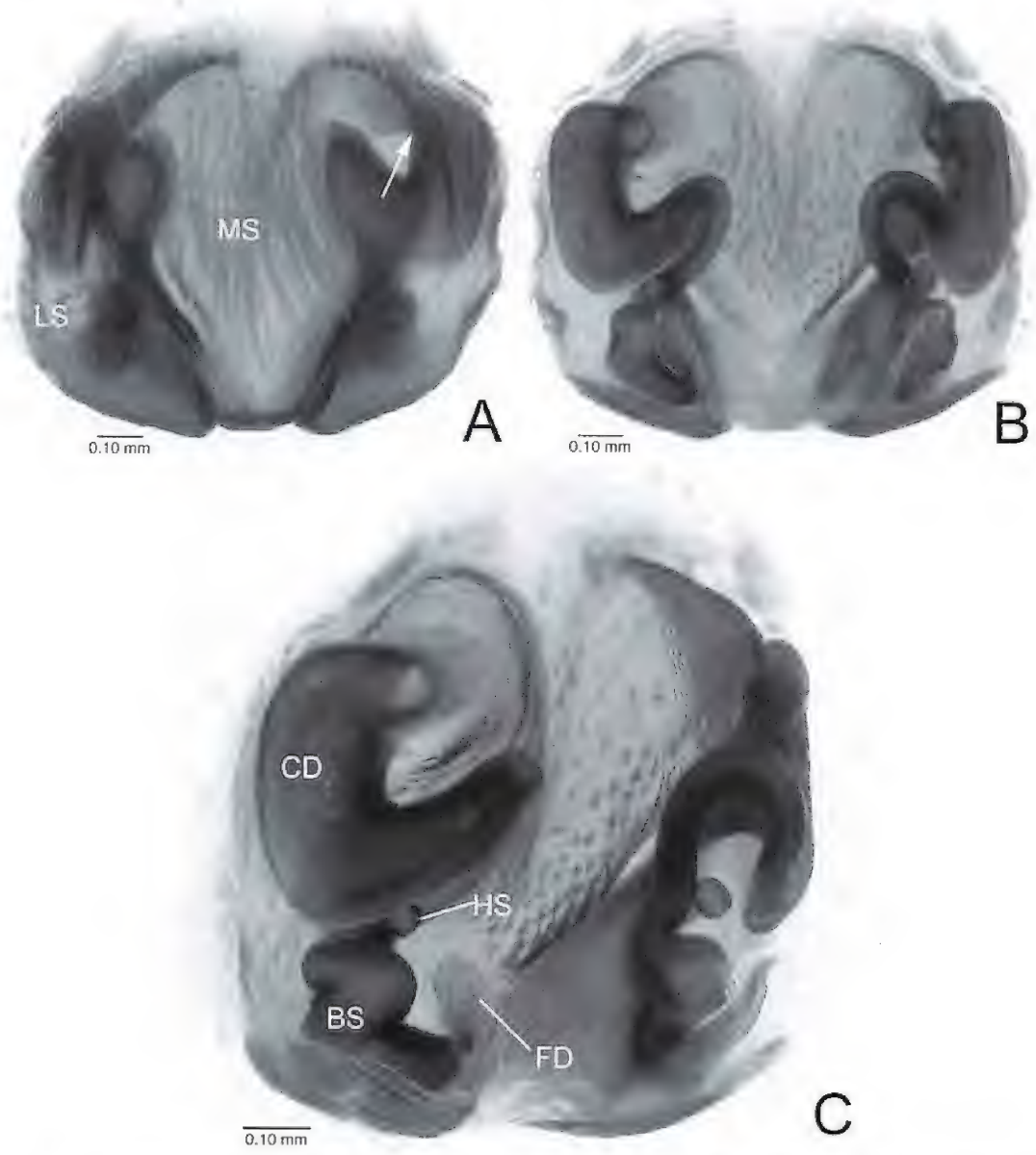

FIGURE 15. *Mahafalytenus fo*, sp. nov. Female genitalia, holotype. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view. C. Vulva, lateral view. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector.

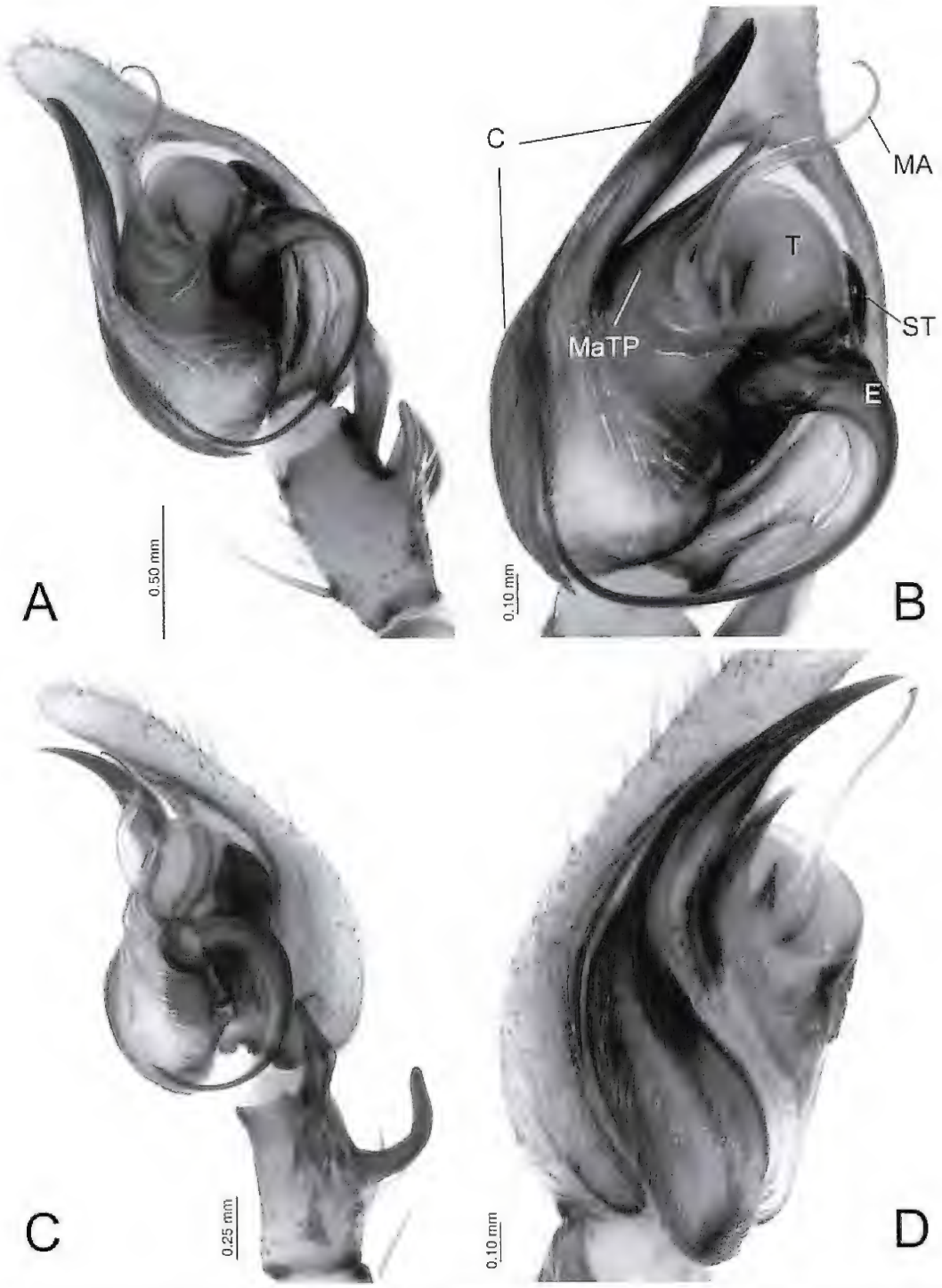

FIGURE 16. *Mahafalytenus fo*, sp. nov. Left palp, male CASENT9014199. A. Ventral view. B. Close up of ventral view. C. Retrolateral view. D. Close up of prolateral view. C= conductor, E= embolus, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, ST= subtegulum, T= tegulum.

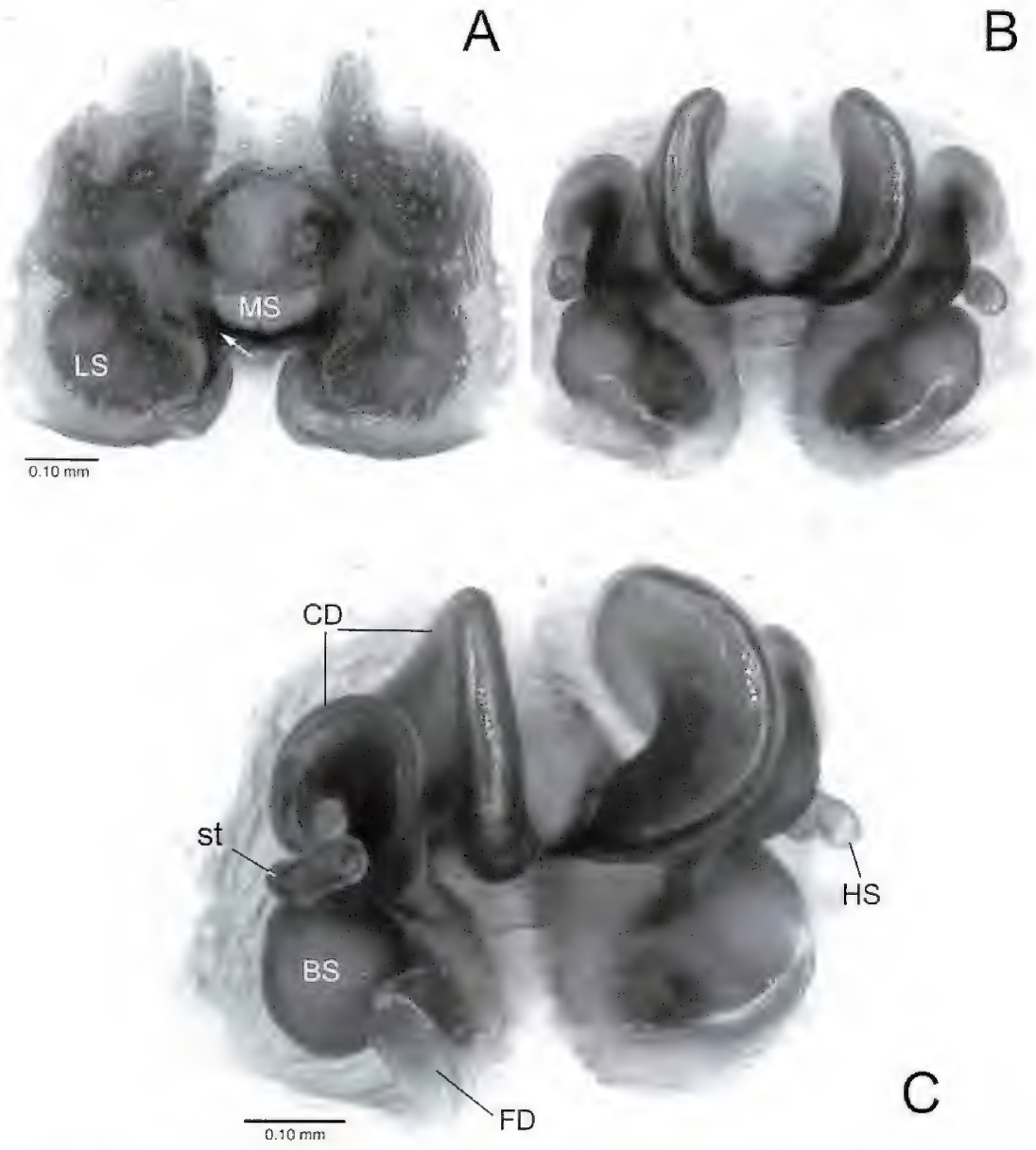

FIGURE 17. *Mahafalytenus fohy*, sp. nov. Female genitalia, holotype. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view. C. Vulva, lateral view. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector, st= stalk of spermatheca.

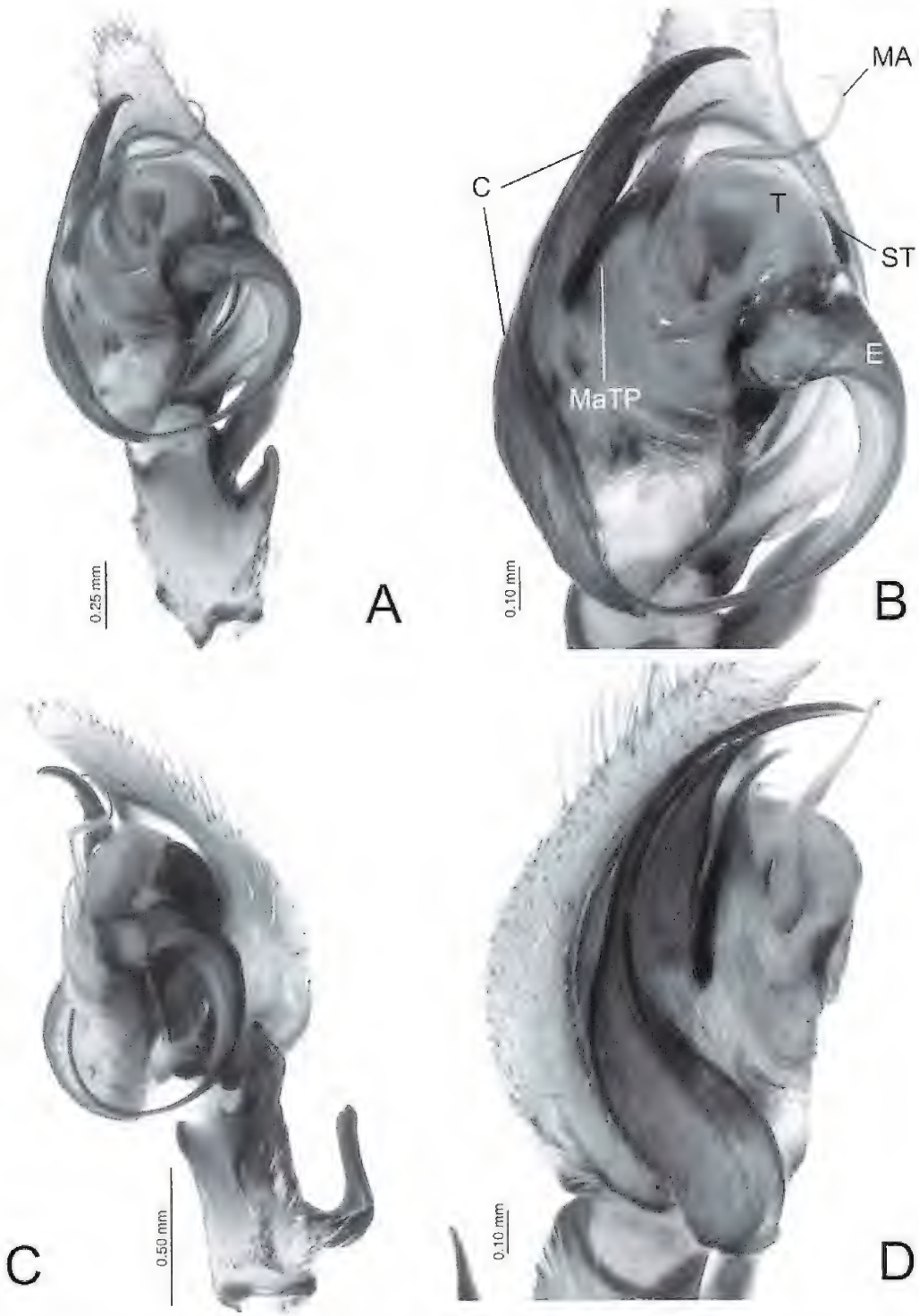

FIGURE 18. *Mahafalytenus fo*, sp. nov. Left palp, male CASENT9021948. A. Ventral view. B. Close up of ventral view. C. Retrolateral view. D. Close up of prolateral view. C= conductor, E= embolus, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, ST= subtegulum, T= tegulum.

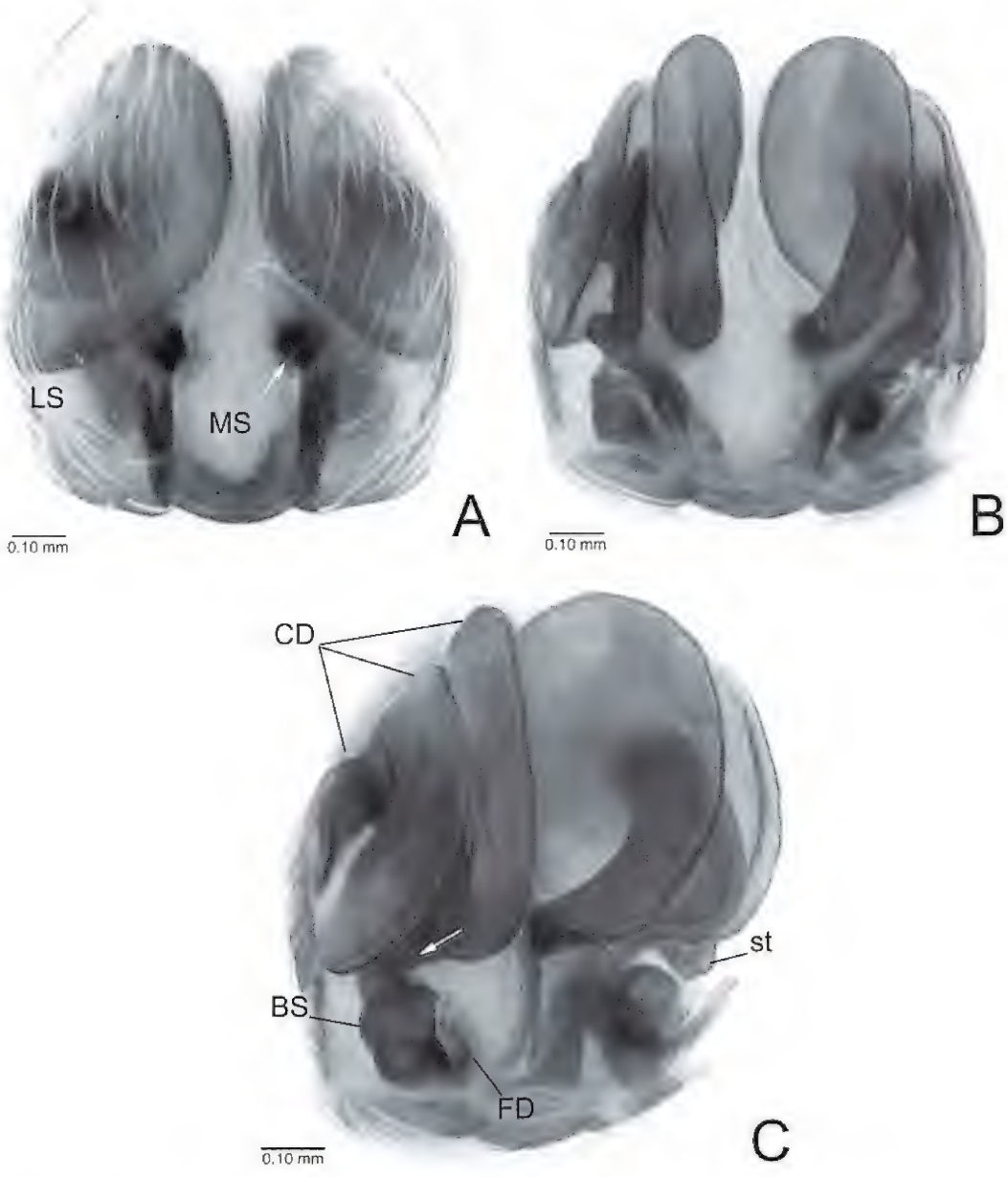

FIGURE 19. *Mahafalytenus hafa*, sp. nov. Female genitalia, holotype. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view. C. Vulva, lateral view, arrow to head of spermatheca. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector.

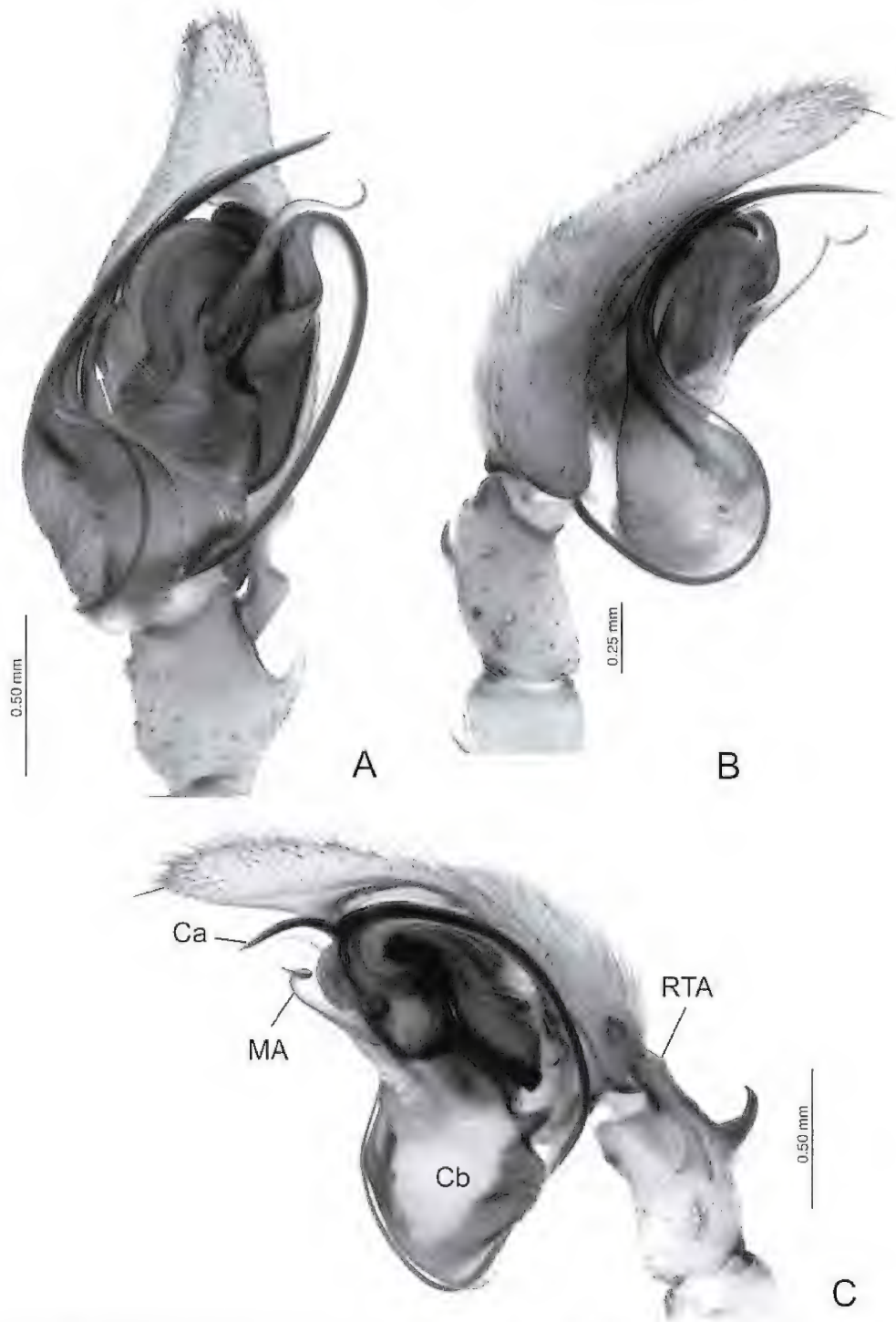

FIGURE 20. *Mahafalytenus hafa*, sp. nov. Left palp, male CASENT9014507. A. Ventral view, arrow to MaTP. B. Prolateral view. C. Retrolateral view. C= conductor, Ca= apex of conductor, Cb= base of conductor, MA= median apophysis, MaTP=*Mahafalytenus* tegular process, RTA= retrolateral tibial apophysis.

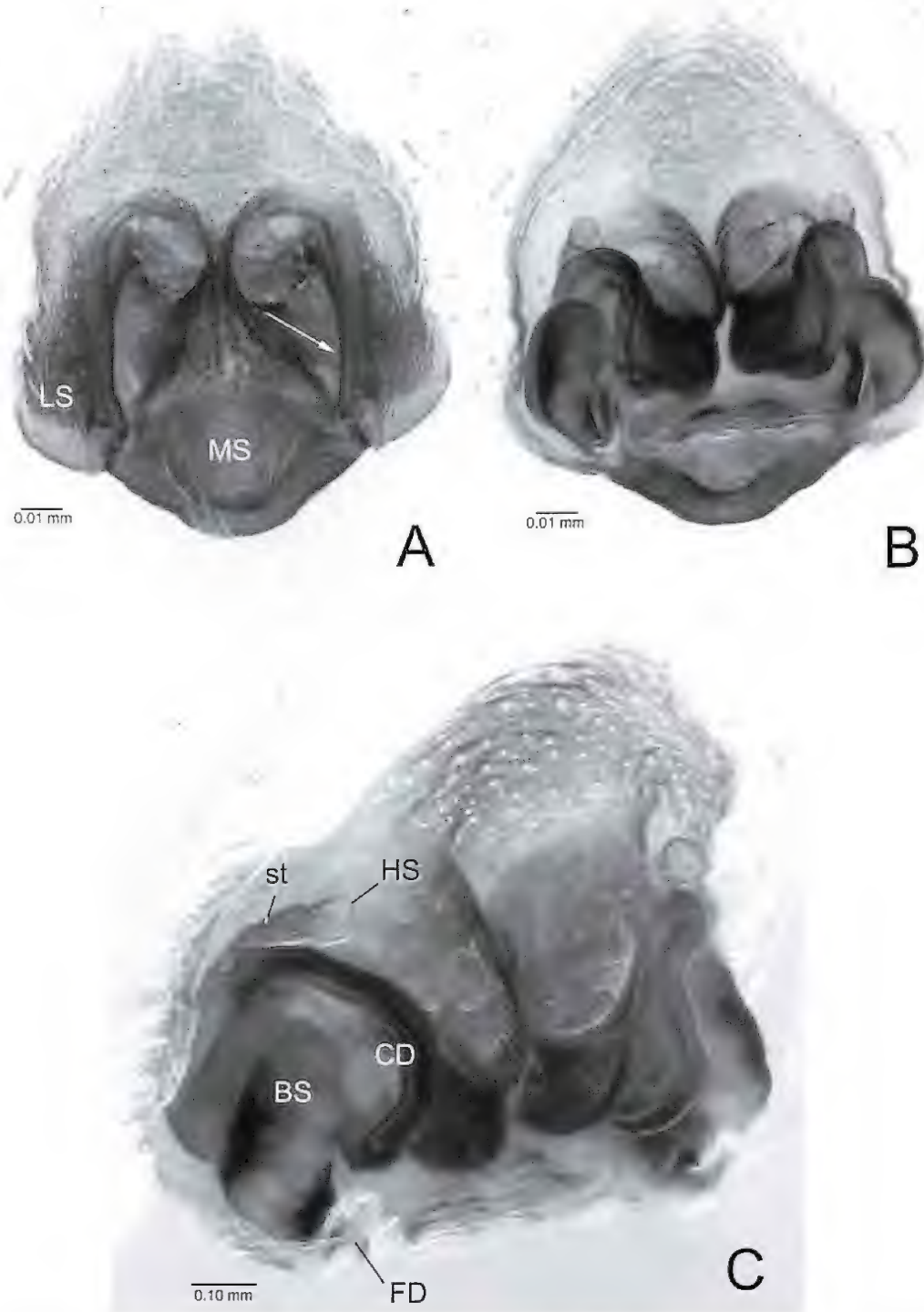

FIGURE 21. *Mahafalytenus isalo*, sp. nov. Female genitalia, holotype. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view. C. Vulva, lateral view. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector, st=stalk of spermatheca.

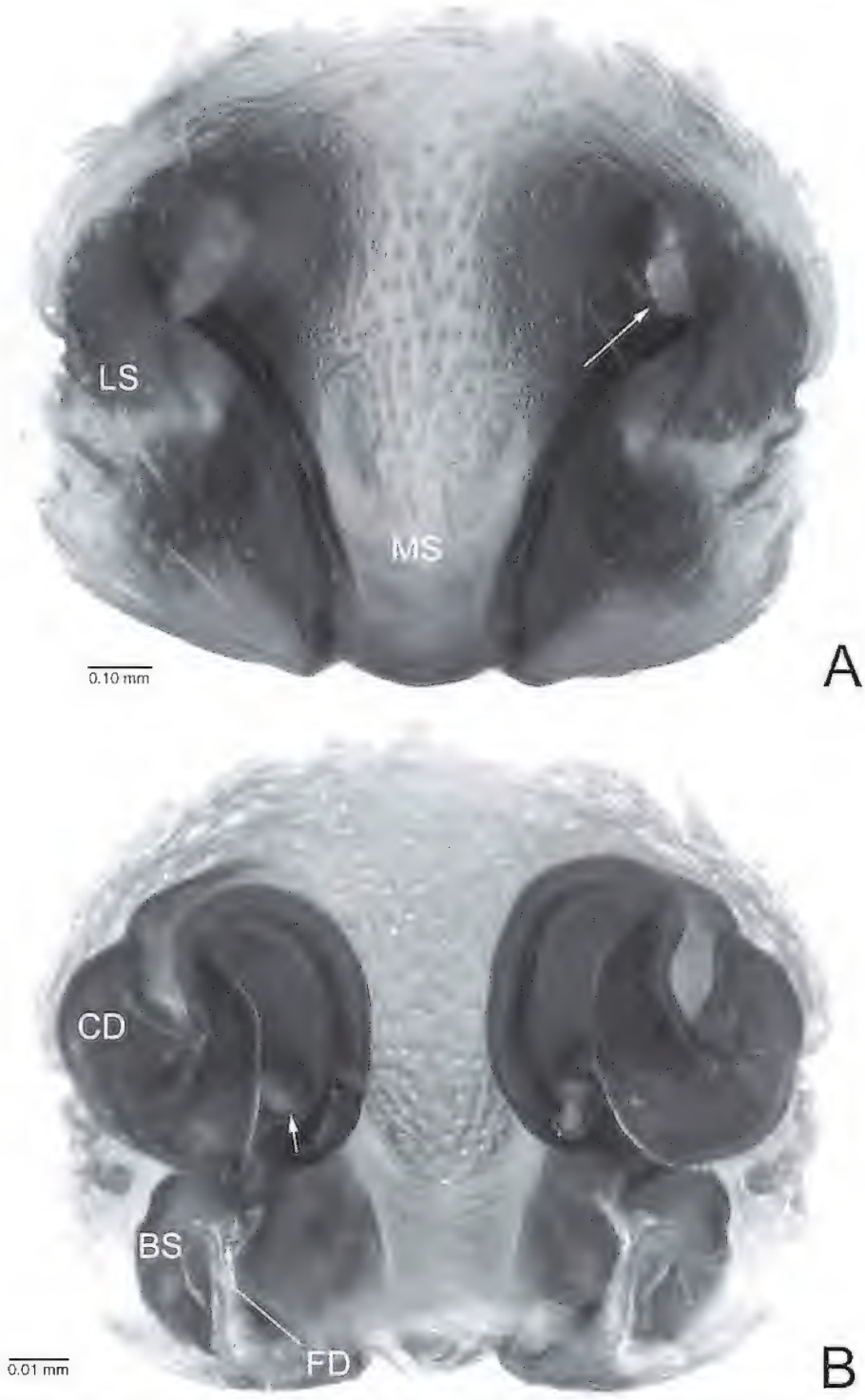

FIGURE 22. *Mahafalytenus osy*, sp. nov. Female genitalia, holotype. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view, arrow to head of spermatheca. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, LS= epigynal lateral sector, MS= epigynal median sector.

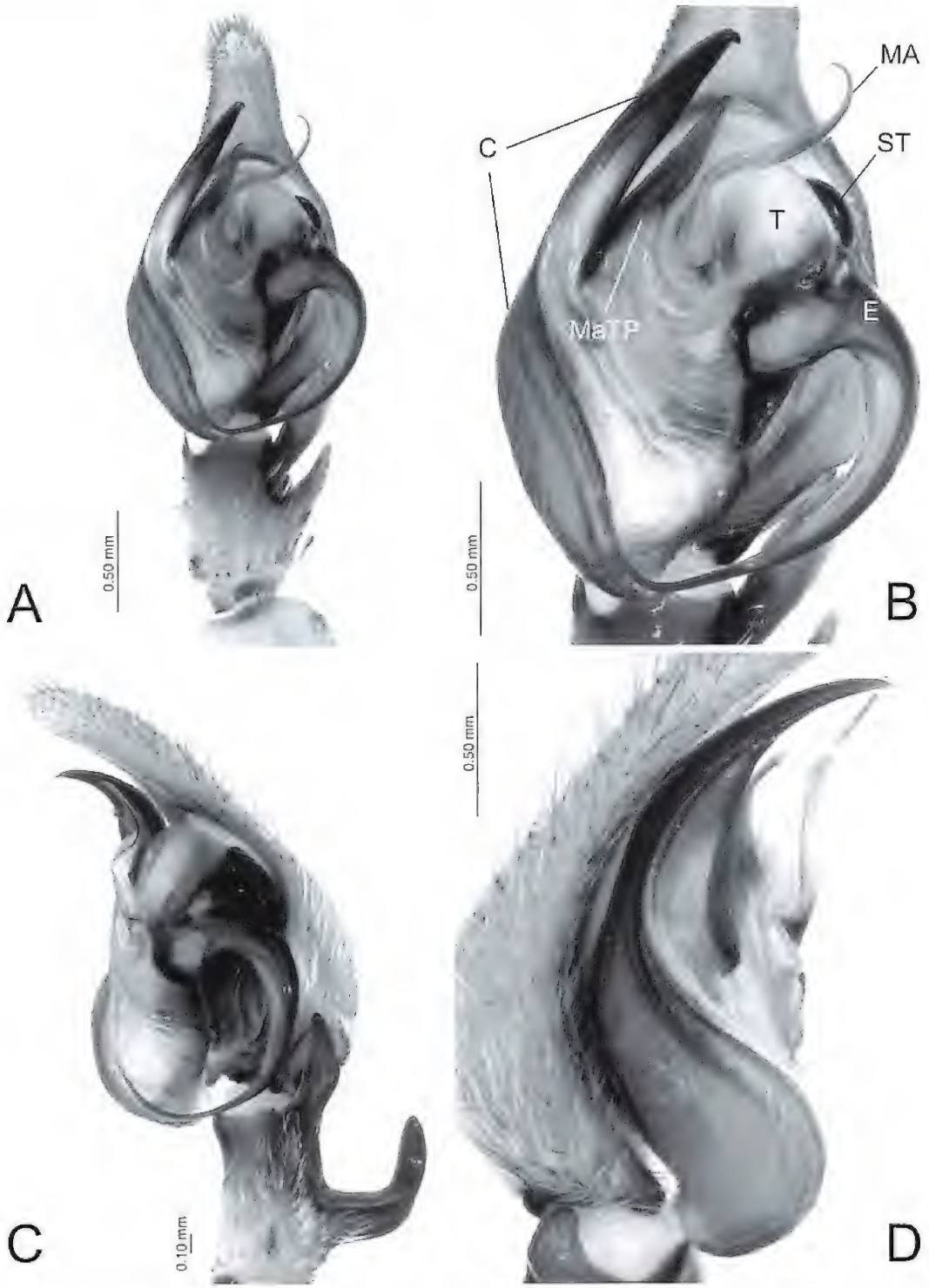

FIGURE 23. *Mahafalytenus osy*, sp. nov. Left palp, male CASENT9021811. A. Ventral view. B. Close up of ventral view. C. Retrolateral view. D. Close up of prolateral view. C= conductor, E= embolus, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, ST= subtegulum, T= tegulum.

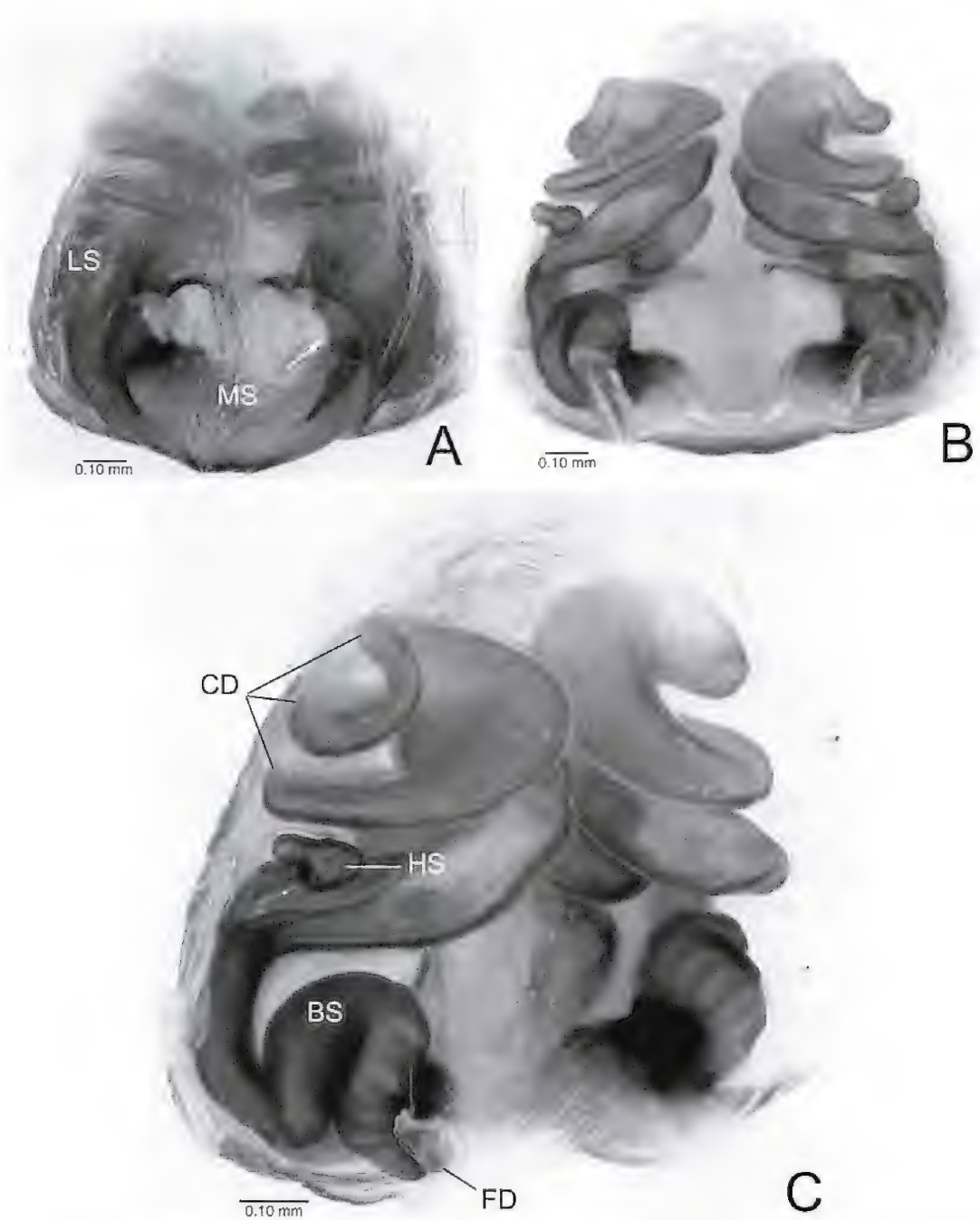

FIGURE 24. *Mahafalytenus paosy*, sp. nov. Female genitalia, holotype. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view. C. Vulva, lateral view. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector.

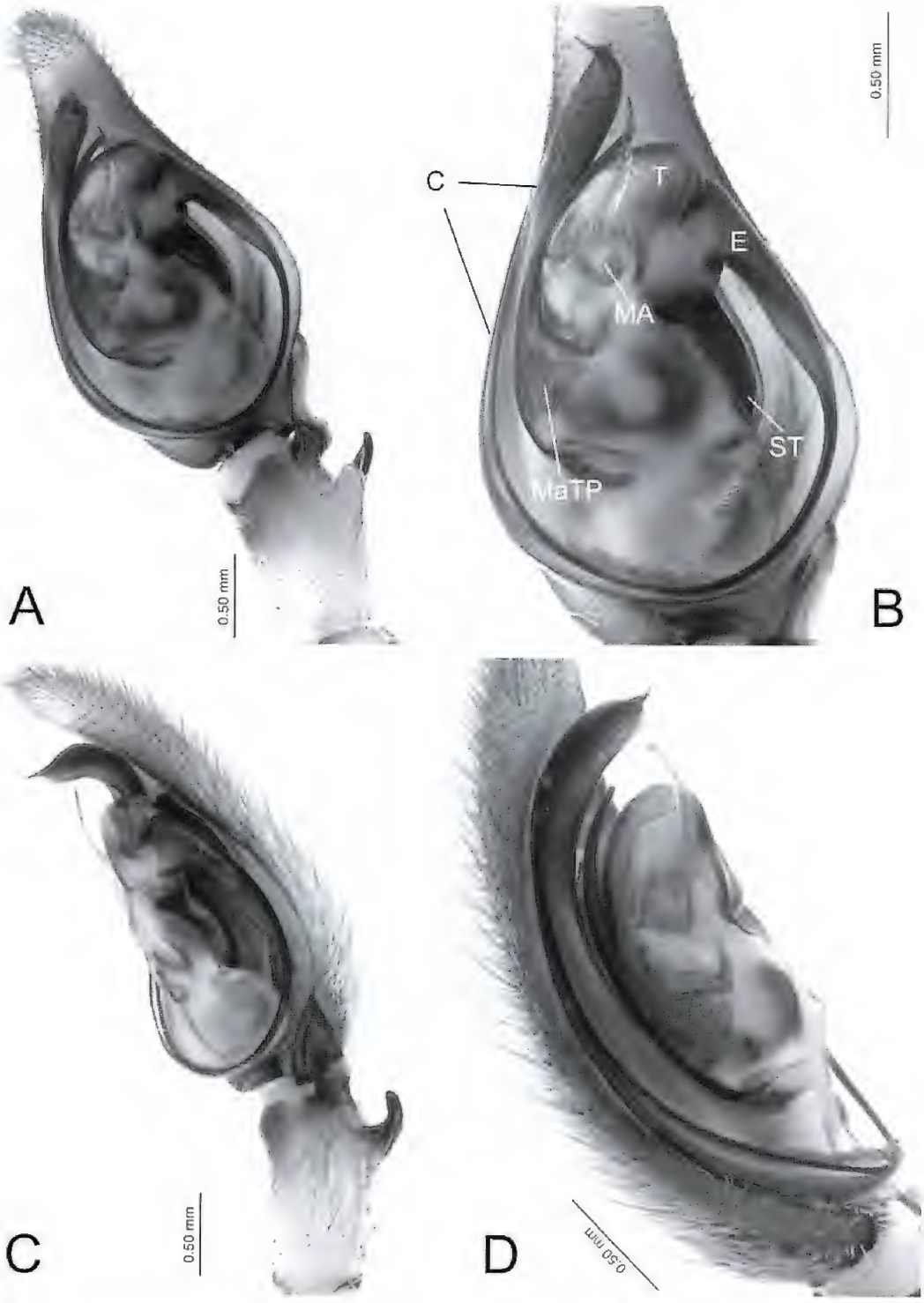

FIGURE 25. *Mahafalytenus paosy*, sp. nov. Left palp, male CASENT9021947. A. Ventral view. B. Close up of ventral view. C. Retrolateral view. D. Close up of prolateral view. C= conductor, E= embolus, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, ST= subtegulum, T= tegulum.

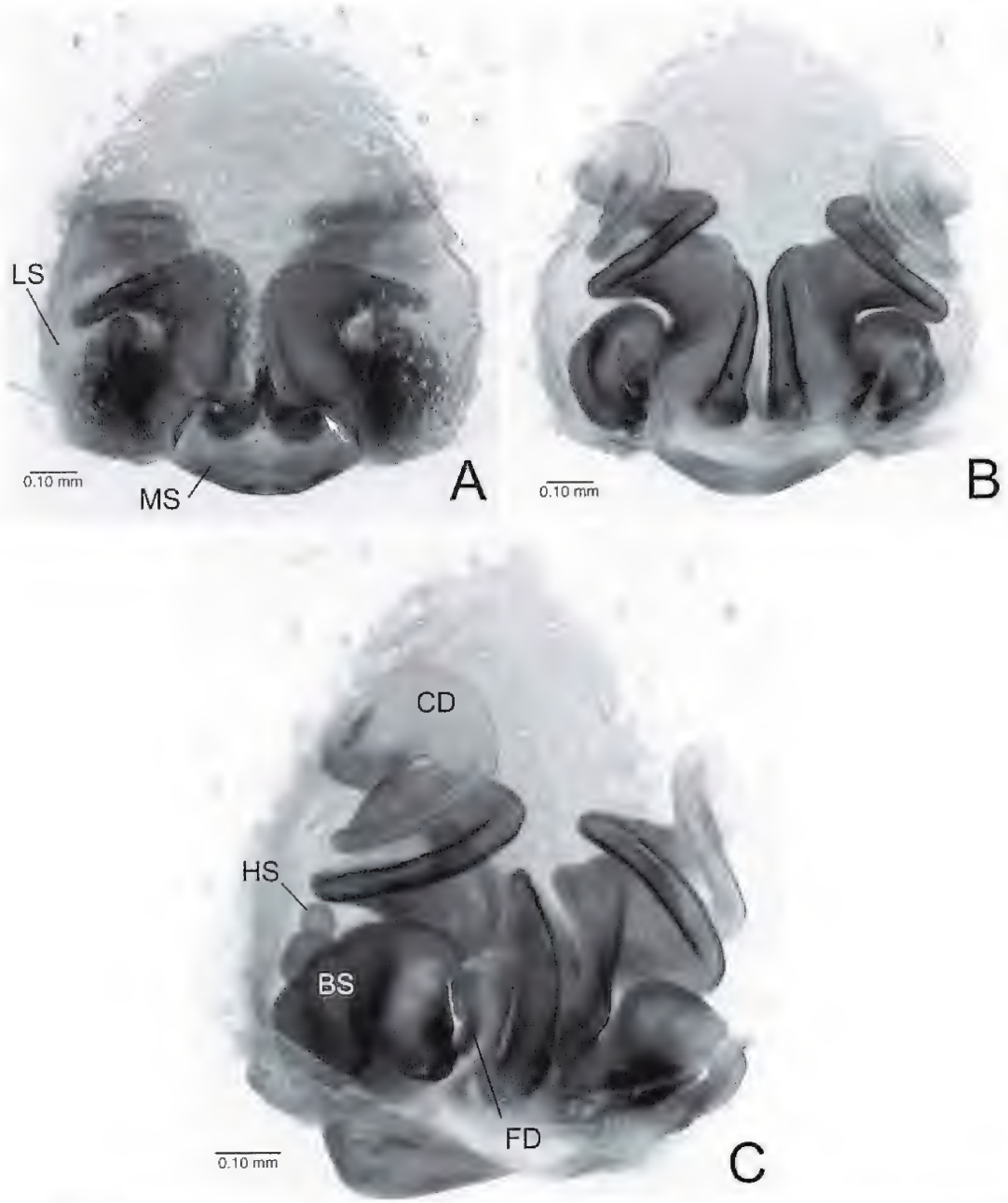

FIGURE 26. *Mahafalytenus tsilo*, sp. nov. Female CASENT9010440. A. Epigynum, ventral view; arrow to copulatory opening. B. Vulva, dorsal view. C. Vulva, lateral view. BS= base of spermatheca, CD= copulatory duct, FD= fertilization duct, HS= head of spermatheca, LS= epigynal lateral sector, MS= epigynal median sector.

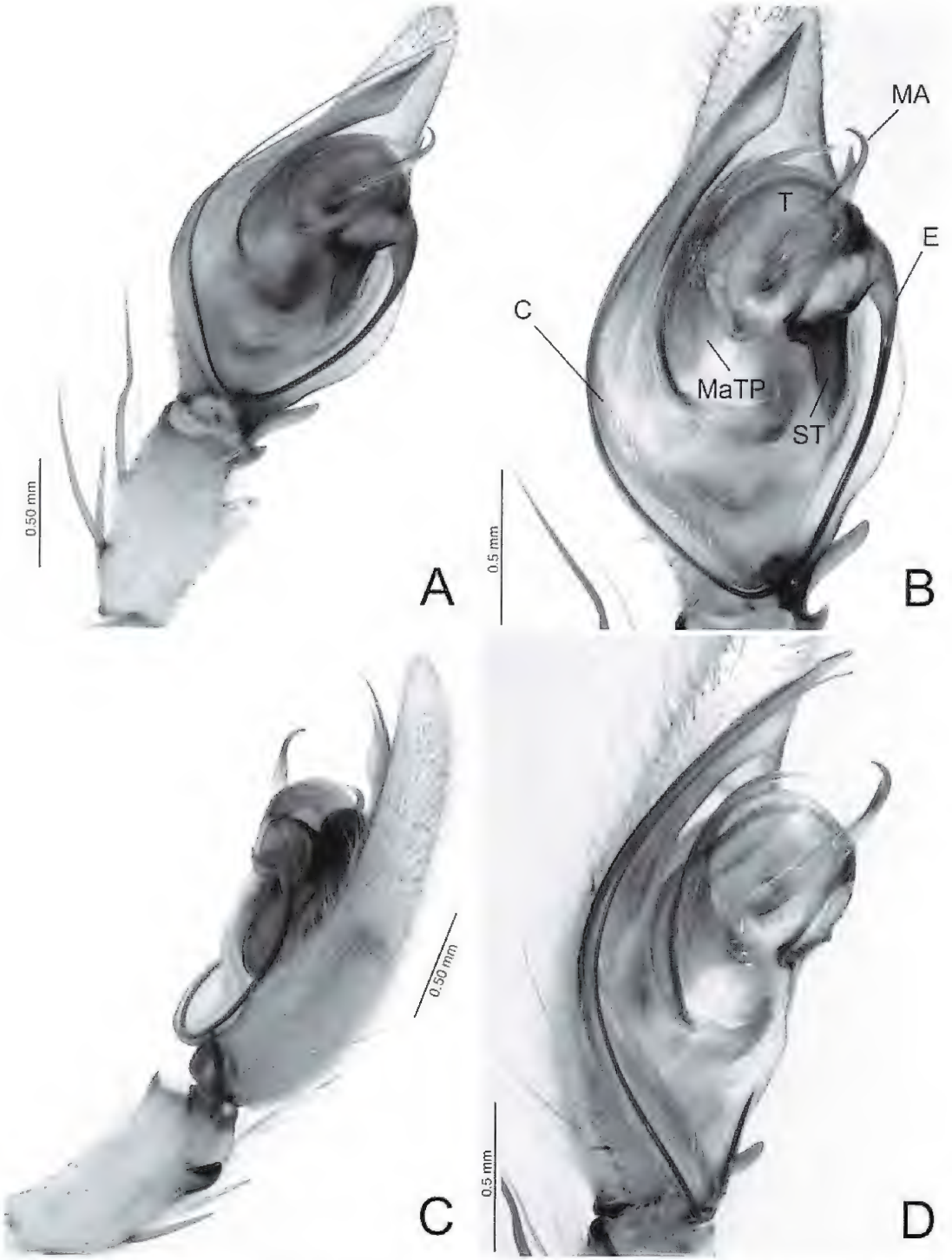

FIGURE 27. *Mahafalytenus tsilo*, sp. nov. Left palp, male CASENT9021811. A. Ventral view. B. Close up of ventral view. C. Retrolateral view. D. Close up of prolateral view. C= conductor, E= embolus, MA= median apophysis, MaTP= *Mahafalytenus* tegular process, ST= subtegulum, T= tegulum.

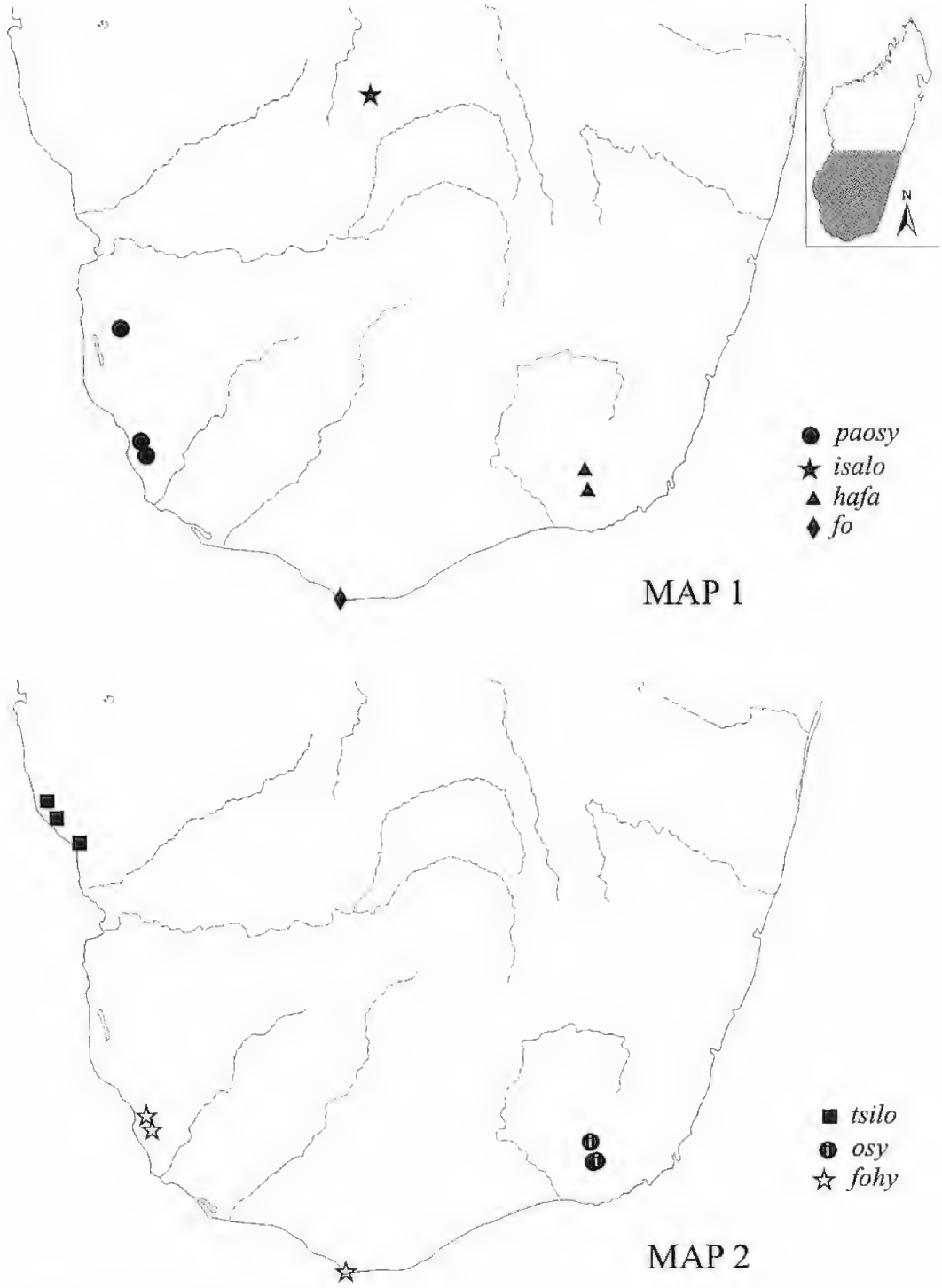

FIGURE 28. Distribution range for *Mahafalytenus* species.

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Redescription and Additional Records of *Arthurella* Albuquerque (Diptera: Muscidae: Cyrtoneurininae)

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Arthurella **(Diptera, Muscidae) is known only from a single species from Chile, *A. nudiseta* Albuquerque. The genus is rare in collections being known previously from only a few specimens. It is placed among the Cyrtoneurininae but its monophyly has not yet been established. The specimens of *A. nudiseta* found in the California Academy of Sciences collection (San Francisco, California) make possible the observation of different color patterns and sizes, as well as the expansion of the known geographical distribution. Color figures showing patterns of mesothoracic dorsum, pleurae and abdomen are given.**

The genus *Arthurella* was described by Albuquerque (1954) for *A. nudiseta*, based on males (erroneously mentioned as female at the beginning of the original description) from Chile (El Canelo and Valparaiso). The female and puparia were first described by Lopes (1985), based on material reared from fungi (Agaricacae) and were later redescribed by Araujo and Couri (1992), who also described the proboscis. Although further mention of the genus or species has been restricted to catalogs (Pont 1972; Carvalho et al. 1993; Carvalho et al. 2005) and notes on the type (Lopes et al. 1997), in 2002, Couri and Carvalho did present a brief diagnosis of the genus with comments on its systematic position.

Since the original description no other species have been added to *Arthurella*. It was originally placed in the subfamily Phaoninae, but now it is referred to the Cyrtoneurininae (Carvalho et al. 2005), a subfamily not currently considered monophyletic.

Specimens of the genus are rare in collections, especially males, being known previously from only three specimens. According to the original description, the holotype male and two paratype males were sent back to the collector, T. Ramires, and it seems unlikely that they were later deposited at Universidad de Chile (Santiago, Chile) (Carvalho et al. 2005). These are the only known male specimens mentioned in the literature. All other previously studied specimens are deposited in the collection of Museu Nacional, Rio de Janeiro — about 30 females from Lluta (Arica), all reared from Agaricaceae.

Recently, we had the opportunity of examining a large and hitherto unreported series in the collections of the California Academy of Sciences. Because of this, we can now report on the different color patterns and sizes, as well as additional geographic records.

As noted above, the monophyly of the genus has not yet been established. Thus, new information that is derived from these newly studied materials, and that includes both new data on morphology as well as the new localities, will be useful for future phylogenetic and biogeographical studies of the Muscidae. This should be especially true as they relate to the biogeography of southern

South America (for several recent studies see, for example, Carvalho 1999, Carvalho and Couri 2002, Couri and Carvalho 2000).

Color figures showing color patterns of mesothoracic dorsum, pleurae and abdomen are given.

Materials and Methods

The studied material belongs to the California Academy of Sciences (CAS, San Francisco, California) collection. Three specimens will be deposited at Museu Nacional, Rio de Janeiro collection (MNRJ) as indicated in the material examined. The specimen reared from fungi, with the dry puparium pinned, belongs to the MNRJ collection.

The color photos were made using Syncroscopy/JVC Auto-Montage with Leica M 420 optical microscope.

Genus *Arthurella* Albuquerque

Type species: *Arthurella nudiseta* Albuquerque, 1954

Diagnosis.— Eyes with sparse fine and short cilia; one pair of long ocellar setae; arista bare; prosternum, anepimeron and meron setulose; dorsocentrals 2:4; presutural acrostichals 2, intra-alars 2; katepisternals 2:2; vein R_1 with dorsal setulae on basal half (or more in some specimens); vein R_{4+5} setulose on both surfaces on basal sixth; veins R_{2+3} and R_{4+5} divergent apically; mid tibia with 4 setae on posterior surface; hind tibia with calcar; sternite 1 bare.

Distribution.— Chile (Arica, Coquimbo, Mendonza, Santiago and Valparaiso) and Argentina (Santa Cruz).

Remarks.— Coquimbo and Mendonza in Chile are new geographic records in this country. The genus is also recorded from Argentina for the first time.

Arthurella nudiseta Albuquerque, 1954

Holotype.— Male, deposited at (?) Universidad de Chile, Santiago, Chile, labeled as "El Canelo. 1-XII-1944, T. Ramires col."

Male.— Length. Body: 5.2–7.5 mm; wing: 4.5–6.0 mm.

General coloration.— Frons dark brown, lunule dark brown or reddish in female; fronto-orbital plate and gena dark brown, silver pollinose. Palpus yellow; antenna with pedicelum reddish and flagellum brown, reddish at base in some specimens. Dorsum of mesonotum dark or pale brown with grayish pollinosity, with four shiny black vittae; scutellum yellow on apical two thirds (Figs 1–2); pleura dark or pale brown with gray pollinosity; post-pronotum concolorus with mesonotum or yellowish; anterior spiracle yellow (Figs. 3–4); calypters whitish hyaline, and halter yellow. Wing hyaline. Legs with fore femur brown, except at apex; mid and hind femora brown on basal half; the brown areas of femora can be more extensively yellow, especially on females; all tibia and tarsi yellow. Abdomen yellow, brown laterally, with median dorsal brown vitta, posterior margins of tergites 1+2–4 brown ; tergite 5 in male brown, with yellow apex (Fig. 5); abdomen in female with median brown vitta varying in width, but usually thinner than in male; sternite 5 yellow, with a brown median vitta (Fig. 6); abdomen can be more extensively yellow in female (Fig. 7).

Head.— Holoptic; antero-internal facets developed. Frontal row with 6 pairs of setae. Inner vertical pair of setae a little longer than outer pair. Antennae inserted at medium level of eyes; flagellomere short, measuring about 1.3–1.5 times length of the pedicelum. Palpi slightly clavate.

Thorax.— Dorsocentrals 2:4; presutural acrostichals 2; 3 postpronotals; 1 presutural; 2 intralars; 2 supralares; 2 postsupralares. Notopleuron with two setae, similar in size. Scutellum with

thin basal and pre-apical pairs of setae and strong sub-basal, pre-apical lateral, and apical ones. Anepisternum with a series of 6–8 strong setae; 1 fine and long and 2–3 shorter and thinner setae on anterior angle. Katepisternals 2:2. Anepimeron setulose on its posterior half. Katepimeron with 2–3 fine setae. Prosternum setulose. Inferior calypter about 1.8–2.0 the length of the superior. Vein R_1 with dorsal setulae on basal half (or more in some specimens); vein R_{4+5} setulose on both surfaces on basal sixth of vein R_{4+5} and M_{1+2} a little divergent to apex. Fore femur with rows of dorsal, ventral and posterodorsal setae; fore tibia with 3 short anterodorsal setae on basal two-thirds; one preapical seta on dorsal surface and one posteroventral seta. Mid femur with 4–5 posteroventral short setae on basal third; one preapical dorsal and 3 posterior to posterodorsal; mid tibia with 4 posterior setae and apical setae on anterodorsal, dorsal, and ventral surfaces. Hind femur with a complete anterodorsal row of setae; anteroventral surface with 3–5 setae on apical third; hind tibia with 3 short setae on middle third of anteroventral and anterodorsal surfaces; posterodorsal surface with a strong calcar, pre-apical anterodorsal seta present.

TERMINALIA.— As in Albuquerque (1954).

FEMALE.— Length. Body: 5.0–6.5 mm; wing: 4.5–6.0 mm

Differs from male as follows: interocular space about one third of head width; interfrontal cruciate setae present; fore tibia also with 1 median and 1 submedian posterodorsal setae, the ones on anterodorsal surface more developed than in male

OVIPOSITOR.— As in Araujo and Couri (1992).

PUPARIUM.— All covered by sand grains (Fig. 8). Description as in Araujo and Couri (1992).

MATERIAL EXAMINED.— ARGENTINA: **Santa Cruz**: 5 km NW Piedra-Buena; low dunes, 130 m, M.E. Irwin and E.I. Schlinger, 10 December 1966 (2 males); 55.6 km S Perito Moreno, 690 m, E.I. Schlinger and M.E. Irwin, 24 November 1966 (5 males, 1 female, 1 male, MNRJ). CHILE: **Arica**: Lluta, Km 30, ex Agaricaceae on 10 June 1976 [with puparium pinned], H. Vargas and A Matta, 18 May 1976, (1 female, MNRJ); **Coquimbo**: Hacienda Illapel, Rio Illapel, 600–900 m, E.I. Schlinger and M.E. Irwin, October 1966 (1 male); **Santiago**: Quebrada de la Plata Fundo,, Rinconada, Maipu, Malaise, 33°31′S 70°47′W, 510 m, M.E. Irwin, 4 August 1966 (1 female); 23 March 1966 (1 male, MNRJ); 24 March 1966 (1 male); 27 March 1966 (2 males, 1 female); 3 April 1966 (1 female); 33°30′S 70°55′W, near Maipu, 510 m, M.E. Irwin, 2 February 1966 (1 male), 10 February 1966 (1 female); 21 February 1966 (1 male); 9 March 1966 (1 female); 24 March 1966 (1 female); 550 m, 24 March 1966 (1 male); 33°34′S 71°14′W, W. Maiz N. Hichins, 20 February 1966 (1 male); 10 March 1966 (1 male, 1 female); 450 m, Malaise-corn, N. Hichins and M.E. Irwin 16 March 1966 (1 male, 1 female); El Canelo, 33°35′S 70°27′W, M.E. Irwin, 9 January 1967 (1 male, 1 female); **Valpariso**: Mendoza: Aconcagua: 4 km S Zappalar, coastal slope, 32°33′S 71°28′W, E.I. Schlinger and M.E. Irwin, 17 July 1966 (1 female, MNRJ)

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Figures 1–8 (right). *Arthurella nudiseta* Albquerque, 1854. (1) Mesothorax, dorsal view, female; (2) Mesothorax, dorsal view, male; (3) Mesothorax, lateral view, female; (4) Mesothorax, lateral view, male; (5) Abdomen, dorsal view, male; (6) Abdomen, dorsal view, female; (7) Abdomen, dorsal view, female; (8) Puparium

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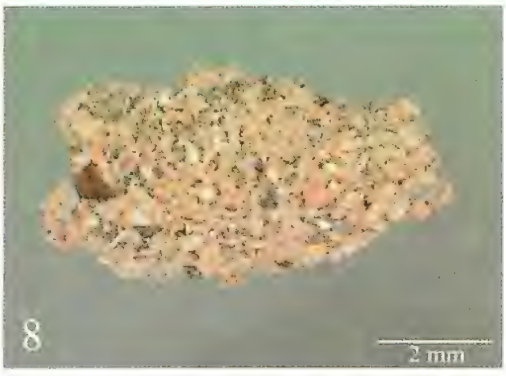
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Biogeography of the Pacific Coast Brittle Star, *Ophioplocus esmarki* (Lyman, 1874) Occurrence Patterns and Environmental Correlates

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This paper presents abundance and distribution patterns of the smooth brittle star *Ophioplocus esmarki* (Lyman, 1874) along the Pacific Coast, with observations on environmental correlates. The three main objectives of this study are: (1) to test the accuracy of existing published range limits for *O. esmarki* via field sampling and museum records, (2) to determine its distribution, and (3) to identify important environmental correlates to *O. esmarki's* presence along the Pacific Coast. Smooth brittle star abundance and distribution along the Pacific Coast were sampled along with substrate and water chemistry. Patterns of species abundance were analyzed according to depth and latitude. Substrate and water chemistry data were investigated by univariate and stepwise logistic regressions in order to determine which variables were significant correlates of *O. esmarki* occurrence. I found that this elusive brittle star is indeed much more common and widespread than was previously thought. *Ophioplocus esmarki's* new northern and southern range limits (50°N and 23°N) are documented and cited in this paper. In field surveys, *O. esmarki* individuals were found from 36°N at Santa Cruz, California south to 27°N in Bahia Asunción, Mexico The most substantive conclusions are that populations are denser in the intertidal than the subtidal, exhibit the abundant center distribution, and large abundances of *O. esmarki* correlate with coarse sand and water temperature ranging 15.2–16.8°C. This offers new data on *O. esmarki's* ideal habitat and can be used for conservation efforts to predict the brittle star's response to climate change, anthropogenic impacts, and to interpret other near shore ophiuroids abundance patterns

KEYWORDS: abundance, distribution, environmental correlates, Ophiuroid, *Ophioplocus esmarki*, Pacific coast, range limits, subtidal.

A fundamental datum in biogeography is the species range, and many studies attempt to delimit and identify environmental correlates with range limits (Terborgh 1971; Root 1988; Carpenter et al. 1993; Miller 1994; Jones and Gladkov 1999; Skov 2000; Scott et al. 2002; Peterson and Kluza 2003,). Accurate accounts of species ranges, their limits, and correlated environmental factors are valuable conservation tools useful in assessing impacts from humans, climate change, habitat fragmentation, natural selection, and extinctions (Root and Sneider 1993; Barry et al. 1995; Brown and Lomolino 1998; Parmesan et al. 1999; Hellberg et al. 2001; Thomas et al. 2001; Karban and Strauss, 2004).

In addition to information from range limits, species abundance and geographic distribution within a range often reveals patterns about important biological and environmental factors (Brown

1984; Brown et al. 1996; Brown and Lomolino 1998). In marine biogeography, research on the abundance and distribution of near shore species has yielded important findings about feeding ecology (Gaymer et al. 2001), dispersal and microhabitats (Gosselin and Chia 1995), substrate selection (Zimmerman et al. 1988), and geographic isolation (Scheltema 1971).

This paper presents abundance and distribution patterns of the smooth brittle star *Ophioplocus esmarki* (Lyman, 1874) (Fig. 1) along the Pacific coast, with observations on environmental correlates. Brittle stars are ophiuroids, a large and understudied class of echinoderms. Sampling for ophiuroids requires focused, intensive searching. Many intertidal and subtidal surveys commonly do not include them as a search objective, obtain them as a search outcome, or deposit them in museums. *O. esmarki* is as under-studied as other ophiuroids, but was chosen for study because information on its abundance, geographic distribution, and environmental correlates would likely be applicable to the biogeography of other closely related, ecologically similar species.

Ophioplocus esmarki has a latitudinally broad (Tomales Bay to San Diego, California) but bathymetrically narrow (to depths of 70 meters) range (Johnson and Snook 1955; Austin and Hadfield 1980; Ricketts et al. 1998; Etchemendy and Wood 2000), which simplifies field sampling. Information on *O. esmarki*'s biogeography is timely because it is a rare and endangered species in Canada (Darling 2000), and research suggests that declining *O. esmarki* populations may indicate their vulnerability to anthropogenic pressure (Addessi 1991; Eckert et al. 2000). In addition, the brooding reproductive strategy of *O. esmarki* may geographically isolate metapopulations, thus creating a patchy distribution (Gaarde and McClenagan 1982).

The three main objectives of this study are: (1) to test the accuracy of existing published range limits for *O. esmarki* via field sampling and museum records, (2) to test Gaarde and McClenagan's patchy-distribution hypothesis, and (3) to identify important environmental correlates with the species presence along the Pacific coast. I hypothesize that the range of *O. esmarki* is larger than is published, especially in the southern direction because San Diego is not a marine zoogeographic boundary. Because *O. esmarki* is a brooder, I agree with Gaarde and McClenagan that populations likely exhibit a patchy distribution. I also expect that, as with other benthic species, there are important physical environmental correlates with *O. esmarki*'s presence that contribute to ideal habitat conditions and their abundance and distribution patterns (Mezquita et al. 2000; Freeman and Rogers 2003).

The following clarifications should facilitate understanding of terminology used in this paper. I define *species range* as a geographic area where an organism has been located, and the *range limit* as the location where a species, "population density over large areas declines to zero" (Brown 1984; Gaston 1996). *Abundance* refers to local population density (number of species per unit area), and I use *distribution* to indicate geographic distribution of a species. The term *environmental correlates* refers to the abiotic variables measured in this study. I use the term *correlative factor* to refer to abiotic factors that are (statistically) significant correlates with *O. esmarki*'s presence.

Methods

Smooth brittle star abundance and distribution along the Pacific coast were sampled in addition to recording information about local substrate and water chemistry. Fieldwork was conducted from Bell Island, Washington south to San Lorenzo Channel, Baja California Sur, Mexico from 2004 to 2006. Fifty-one sites were sampled for *O. esmarki* individuals in intertidal and subtidal waters.

The research sites were selected according to habitat and accessibility. *Ophioplocus esmarki* habitats are typically near shore areas with boulders or cobbles in sandy-mud substrate, generally

FIGURE 1. *Ophioplocus esmarki*, taken at 18 meters depth off of East Santa Rosa Island, California. Photo by author.

on a low sloping beach with sheltered wave exposure (Austin and Hadfield 1980; Ricketts and Calvin 1998). I located these habitats by analyzing topographic and geologic maps, and aerial photos. Each selected site was divided into intertidal and subtidal zones, all at least 50-meters wide (parallel to the shore). Subtidal zones were seaward from intertidal sites in depths of 3 to 18 meters. Latitude and longitude to the nearest 15 meters were determined at every site using a GPS receiver (Garmin Legend Ltd).

INTERTIDAL SURVEY METHODS.— Intertidal zones were searched at low tides less than or equal to -0.4 meters. A 50 meter transect was laid parallel to the water line at the 0.0 mean low water level at slack tide. Ten boulders or large cobbles were overturned within nine randomly selected 3.14 m^2 circle plots (Medeiros-Bergen and Ebert 1995). Each boulder flipped was measured to the nearest centimeter, and the width and length were used to obtain the under rock area as if the rocks were square (Ison and Frerich 1997).

The under-rock substratum was searched for *O. esmarki* individuals, and under each rock surface area coverage of the visibly exposed primary, secondary, and tertiary sediments (Sharman et al. 2002) was estimated from a planar view using a modified Wentworth scale. Identifications were made in the field, and at least two voucher specimens of *O. esmarki* were collected at each site. One water sample was collected and water temperature was measured to the nearest 0.1°C (Aqua Temp underwater thermometer) along the transect at each site.

If no *O. esmarki* individuals were found, then an additional 20–30 minute timed survey was conducted, overturning 70–100 cobbles and boulders (Sagarin and Gaines 2002a). If *O. esmarki*

was located during the timed survey, then the intertidal survey was repeated at a new location and low tide within that site.

Subtidal survey methods.— Subtidal habitats were searched for *O. esmarki* via SCUBA. A research diver and I descended to a minimum of three meters and proceeded along a compass heading perpendicular to each subtidal site to a maximum depth of 18 meters. Ten boulders or large cobbles were overturned in four to nine randomly selected 3.14 m^2 circle plots according to depth (Kushner et al. 1994; Medeiros-Bergen and Ebert 1995). At each circle plot, data on the total number of *O. esmarki* individuals, as well as surface area coverage of primary, secondary, and tertiary under-rock substrate were collected. At least two voucher specimens of *O. esmarki* were also collected at each site. Water temperature was measured and a water sample was taken at the deepest circle plot. Similar to intertidal surveys, if no *O. esmarki* were found, then a second dive occurred and an intensive timed search (10–20 minutes) was conducted. If *O. esmarki* was located during this timed survey, then the subtidal sampling was replicated in a new offshore location at that site.

Laboratory and data analysis.— Intertidal and subtidal water samples were analyzed for salinity and dissolved oxygen content. Salinity was measured to the nearest 0.1 ppt using a YSI 3200 Conductivity Instrument (K = 1.030 at 25.0°C). Dissolved oxygen was measured to the nearest 0.1 ppm using a Hanna HI 9142 dissolved oxygen meter.

Ophioplocus esmarki abundance was estimated by dividing the total number of individuals at each site by the total under-rock surface area searched. Mean under-rock surface area for each circle plot was estimated using the length and width measured for each rock in the field. Specimen counts were standardized by applying the mean under-rock surface area for each circle plot (1 m^2) to allow for comparisons of species abundance (Piepenburg et al. 1997). These calculated abundances were then grouped according to latitude for analysis using JMP IN version 5 statistical software.

Substrate and water chemistry data were investigated using two different analytical approaches. A series of univariate logistic regressions were employed for each group of variables in the forward, backward, and mixed directions in order to determine which variables were significant correlates of *O. esmarki* occurrence. The two data groups were also combined in a stepwise logistic regression in the forward, backward, and mixed directions to verify that the same variables that emerged as predictors in the univariate analysis also were significant in the combined stepwise analysis.

Museum research.— I visited three museum collections: California Academy of Sciences (CAS), Los Angeles County Museum of Natural History (LACM), and the Royal British Columbia Museum (RBCM) to locate unpublished *O. esmarki* range records. These museums were visited because they contained collections of *O. esmarki*, as determined by their curators. *Ophioplocus esmarki* specimens were verified visually using the key to ophiuroids in Light et al. (1975) and all label data were recorded. Records from the National Museum of Natural History (USNM) and Scripps Institution of Oceanography (SIO) were also analyzed, but the institutions were not visited to verify their collections.

Results

At the 51 sites sampled in this study, a total of 666 *O. esmarki* individuals was found under 2790 boulders and large cobbles. Each boulder's under-rock area ranged from .04-.42 m^2 (M =.10 m^2, SD =.06), and the total under-rock area searched along the coast was 279 m^2 (Table 1).

Range extensions.— The five museum collections yielded 107 records of *O. esmarki* occurrence dating from 1874 (USNM, catalogue numbers 12644 and 12732) to 1997 (LACM, catalogue numbers 97.42-3 and 97.41-7) along the Pacific coast. According to confirmed museum records,

TABLE 1. Names and GPS coordinates for all 51 research sites (ordered from north to south), with abundance, primary substrate, and water temperature data.

Research Site	*GPS Coordinates*	*Total # O. esmarki*	*Area (m^2)*	*# O. esmarki /m^2*	*1° Substrate*[1]	*Water temp (°C)*
Bell Island, WA	N48°35.786 W122°58.932	0	4	0.00	C. Sand	8.1
Turn Island, WA	N48°32.189 W122°58.289	0	4	0.00	C. Sand	8.1
Yachats, OR	N44°18.226 W124°06.494	0	3	0.00	F. Sand	NA
Port Orford, OR	N42°75 W124°50	0	2	0.00	Bedrock	9.1
Ocean Shore, OR	N42°42.765 W124°27.752	0	5	0.00	F. Sand	NA
Trinidad Head, CA	N41°03.416 W124°08.855	0	4	0.00	C. Sand	9.5
Van Damme, CA	N39°16.419 W123°47.438	0	3	0.00	Boulder	9.5
Head Rock, CA	N39°16.419 W123°47.438	0	4	0.00	C. Sand	10.2
Gerstle Cove, CA	N38°33.998 W123°19.916	0	5	0.00	C. Sand	10.6
Ocean Cove, CA	N38°33.241 W123°18.241	0	3	0.00	Pebbles	9
Steamer Lane, CA	N36°57.037 W122°01.591	5	4	1.25	Bedrock	12.7
Lovers Point, CA	N36°37.475 W121°54.985	7	5	1.40	Cobbles	11.7
Montaña DeOro, CA	N35°26.732 W120°85.910	0	1	0.00	Bedrock	NA
Shell Beach, CA	N35°15 W120°65	5	3	1.67	Cobbles	16.5
Refugio, CA	N34°45.849 W120°06.890	50	NA	NA	C. Sand	NA
Emma Wood, CA	N34°17.582 W119°20.356	19	3	6.33	Cobbles	16.8
Cavern Point, CA	N34°03.306 W119°34.000	70	5	14.00	Boulder	16.6
Amphitheater C., CA	N34°03.019 W119°35.372	34	6	8.50	C. Sand	16.2
Leo Carrillo, CA	N34°02.649 W118°56.011	3	6	0.50	Bedrock	15.4
Leo Carrillo, CA	N34°02.649 W118°56.011	0	3	0.00	F. Sand	NA
Las Tunas, CA	N34°02.364 W118°35.940	1	4	0.25	Bedrock	15.8
East Point, CA	N33°56.067 W119°58.301	16	2	8.00	C. Sand	15.2
East Pinnacles, CA	N33°56.150 W119°58.134	50	NA	NA	C. Sand	15.2
Malaga Cove, CA	N33°48.184 W118°23.825	0	6	0.00	C. Sand	18.9
Malaga Cove, CA	N33°48.184 W118°23.825	1	9	0.11	C. Sand	NA
Cabrillo, CA	N33°42.489 W118°17.105	1	4	0.25	C. Sand	14.9
Cabrillo, CA	N33°42.489 W118°17.105	36	9	4.00	Bedrock	NA
Corona Del Mar, CA	N33°35.330 W117°52.088	5	6	0.83	C. Sand	16.2
Corona Del Mar, CA	N33°35.330 W117°52.088	1	9	0.11	Bedrock	NA
Dana Point, CA	N33°27.618 W117°42.570	0	7	0.00	F. Sand	NA
Dana Point, CA	N33°27.618 W117°42.570	0	2	0.00	C. Sand	19.2
Seal Point, CA	N33°25.644 W118°25.419	3	5	0.60	Boulder	19.5
Twin Rocks, CA	N33°25.041 W118°25.53	2	5	0.40	Boulder	19.5
Lower Trestles, CA	N33°22.929 W117°35.308	0	9	0.00	F. Sand	NA
San Onofre, CA	N33°22.469 W117°34.132	0	9	0.00	F. Sand	NA
False Point, CA	N32°48.440 W117°15.987	3	8	0.38	F. Sand	20.6
False Point, CA	N32°48.440 W117°15.987	15	9	1.67	Bedrock	NA
San Miguel,MX	N31°54.077 W116°43.716	47	7	6.71	C. Sand	NA
San Miguel, MX	N31°54.077 W116°43.716	84	8	10.50	C. Sand	NA
Pt. St. Tomas, MX	N31°34.164 W116°41.415	33	5	6.60	C. Sand	15.6
Pt. St. Tomas, MX	N31°34.164 W116°41.415	161	9	17.89	C. Sand	NA
Cuatro Casas, MX	N30°56.017 W116°14.475	9	9	1.00	C. Sand	17.8
San Roque, MX	N27°10.824 W114°23.844	1	4	0.25	C. Sand	NA
B. Asunción, MX	N27°07.475 W114°17.739	0	6	0.00	F. Sand	14.4
B. Asunción, MX	N27°07.475 W114°17.739	4	6	0.67	C. Sand	NA
Pt. Abreojos, MX	N26°43.417 W113°32.765	0	8	0.00	F. Sand	NA
Swanee Reef, MX	N24°23.546 W 110°18.288	0	9	0.00	C. Sand	NA
El Merito, MX	N24°18.024 W110°20.257	0	9	0.00	C. Sand	NA
Pt. Conejo, MX	N24°04.508 W111°00.468	0	7	0.00	Shell	24.4
Pt. Conejo, MX	N24°04.508 W111°00.468	0	9	0.00	C. Sand	NA
San Pedrito, MX	N23°22.011 W110°12.133	0	9	0.00	Pebbles	NA
Totals	**51 Research Sites**	**666**	**279 m^2**	**N/A**	**N/A**	**N/A**

[1] Under-rock substrate classified using a modified Wentworth scale: F. Sand 1/16-1/4 mm; C. Sand 1/4-2mm; pebbles 4-65 mm; cobbles 64-256 mm; boulders 256-2048 mm.

O. esmarki's published range limits are extended north to Quatsino Sound, Vancouver Island (RBCM, catalogue number 180-52), and south to the San Lorenzo Channel, Mexico (LACM, catalogue number 607-36) see Appendix 1.

ABUNDANCE AND DISTRIBUTION PATTERNS.— In field surveys of the 51 research sites, *O. esmarki* individuals were found from 36°N at Santa Cruz, California south to 27°N in Bahia Asunción, Mexico. According to abundance data, *O. esmarki* population densities are highest near the center of its range (17.89 individuals/m^2 at Punto Santo Tomas, Baja California Norte; and 14.00 individuals/m^2 at Cavern Point, California) and decrease both to the north and south. At six of seven sites where both the intertidal and subtidal habitats were surveyed, *O. esmarki* individuals are more abundant in the intertidal (M = 4.99 individuals/m^2, SD = 6.77) than in the subtidal (M = 2.11 individuals/m^2, SD = 3.11) (Fig. 2). Two caveats exist for this data. First, since the sampling sites were preselected for habitat suitability, the measurements of density are biased. Second, since the under-rock areas were treated as rectangles, the abundance data reported here is slightly lower than in the field.

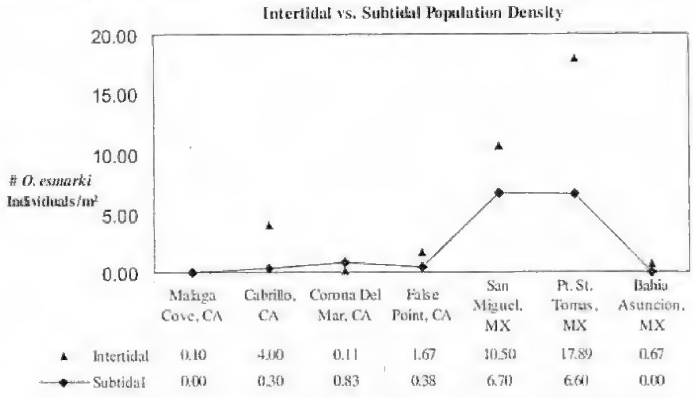

FIGURE 2. At six of seven sites where both the intertidal and subtidal habitats were surveyed, *O. esmarki* individuals were more abundant in the intertidal.

ENVIRONMENTAL CORRELATES.— A series of univariate logistic regressions in addition to a combined stepwise logistic regression yielded Chi-squared values for all environmental data. Among all environmental correlates measured, primary under-rock substrate, and water temperature are significant correlative factors of *O. esmarki's* occurrence. The most common primary under-rock substrate type, coarse sand (¼–2 mm) is a significant correlative factor for the occurrence of *O. esmarki* (χ^2 [N = 49] = 0.02, $p < 05$). Secondary and tertiary under-rock substrate are not significant. The occurrence of *O. esmarki* correlates significantly with water temperature (χ^2 [N = 29] = 0.02, $p < .05$) for temperatures ranging from 11.7°C to 19.5°C (M = 16.4°C, SD = 2.3). Dissolved oxygen (χ^2 [N = 35] = 0.32, $p > .05$) and salinity (χ^2 [N = 35] = 0.09, $p > .05$) do not yield significant Chi-square values and, thus, were not significant correlates to the species' occurrence.

Analysis of the eight sites where abundances of *O. esmarki* are greatest (> 6 individuals/m^2) accents the following about habitat preference: the primary substrate is coarse sand (¼–2 mm) (six of the eight sites), dissolved oxygen ranges from 7.9–8.1 ppm (M = 8.01 ppm, SD = .07), salinity ranges 32.8–33.4 ppt (M = 33.23 ppt, SD = .20), and water temperature ranges from 15.2–16.8°C (M = 16.08°C, SD = .67).

DISCUSSION

RANGE EXTENSIONS.— The data collected on species range, abundance, and distribution of *Ophioplocus esmarki* show that this elusive brittle star is indeed much more common and widespread than was previously thought. New northern and southern range limits (50°N and 23°N) for *O. esmarki* are documented in this paper. The species is most abundant (M > 6 individuals/m^2) between 34°N at Cavern Point, California and 31°N at Punto Santo Tomas, Mexico.

This is within the Californian marine zoogeographic province (34°N to 27°N), a zone of mixing where eurythermic species of both southern and northern origin are brought into contact (Briggs 1974; Newman 1979; Kaustuv and Martien 2001; Wares et al. 2001). While *O. esmarki* is not one of the 30% of species endemic to the province, it is found in much lower abundances (0–1.67 individuals/m^2) north of the province limits, and is not found at all to the south (Briggs 1974). This suggests that *O. esmarki* thrives in the subtropical-temperate waters of the California province.

ABUNDANCE AND DISTRIBUTION PATTERNS.— Two additional patterns emerged from the abundance and distribution data: (1) *O. esmarki* is most abundant in the central portion of its range, and (2) *O. esmarki* is more abundant in the intertidal compared to the subtidal.

Abundant center distribution: Although not a statistically significant normal distribution (Shapiro-Wilk W = 0.828077), *O. esmarki's* abundance is greatest (M > 6 individuals/m^2) at the center of its range (34°N to 31°N) and declines toward the northern and southern range limits (Sall et al. 2005). This pattern follows the "abundant center distribution" (ACD) (see Sagarin and Gaines 2002b), which has been well considered in the literature (Preston 1948; Wulff 1950; Udvardy 1969; May 1975; Gaston and Blackburn, 2000; Sagarin and Gaines 2002a, 2002b). Recent research by Murphy et al. (2006), suggests that this pattern may be better described as the "abundant core distribution" (ACD), with core habitat existing near a range center extending out 60–70% toward the range edges. The ACD has been observed in a wide variety of organisms over a range of spatial scales and is most often attributed to marine invertebrates with a pelagic dispersal phase such as *Fissurella volcano* (Reeve, 1849) and *Tegula funebralis* (Adams, 1854) (Grinnell 1922; Cain 1944; Brown 1984; Sagarin and Gaines 2002a). However, *O. esmarki* is ovoviviparous, its young developing within bursae, and would not be expected to exhibit the ACD.

I hypothesize that *O. esmarki* exhibits the ACD largely due to its rafting capabilities. Similar to *O. esmarki*, *Amphipholis squamata* (Chiaje, 1828) is an ovoviviparous ophiuroid that floats on debris and has a high tolerance for environmental change that contributes to its cosmopolitan distribution (Highsmith 1985; Alva and Vadon 1989). Individuals of *O. esmarki* have been documented rafting on kelp (Bushing 1994), which is likely an important vector for dispersal, especially to offshore islands, and contributed to its ACD.

In our field survey, no *O. esmarki* individuals were located north of 36°N or south of 27° N. I hypothesize this is because populations of *O. esmarki* are rarer toward the edges of its range, as often occurs in other marine species like *F. volcano*, *T. funebralis*, and *Nucella canaliculata* (Duclos, 1832) (Sagarin and Gaines 2002a; Sorte and Hofmann 2004). These data support the hypothesis that *O. esmarki* is best adapted to the subtropical-temperate waters of the California province.

Intertidal vs. Subtidal: The second major abundance pattern is that *O. esmarki* is more abundant in the intertidal than in the subtidal. Although the abundance data for the intertidal and subtidal were not significantly different at the 5% level ($p = .33$, $P > .05$), the general pattern is evident (Fig. 1). *Ophioplocus esmarki*'s abundant core is located well within subtropical (defined as 23° to 35°N) waters, and thus follows the pattern along the Pacific Coast that ophiuroids are often more abundant intertidally in tropical and subtropical water (Austin and Hadfield 1980). I hypothesize that *O. esmarki* is more abundant in the intertidal because of the higher concentration of complex substrate (Drolet et al. 2004; Kostylev et al. 2005), benthic food supply, and reduction in mobile subtidal predators such as fish, crabs, and lobster (Rilov and Schiel 2006). Even within the intertidal zone, *O. esmarki* exhibits this pattern (at False Point, California) with higher densities at -.1m tide level (14.55 individuals/m^2) than at the -.3m tide level (10.75 individuals/m^2) (Presiado, unpublished data 2001).

ENVIRONMENTAL CORRELATES.— Previous studies illustrate that physical environmental vari-

ables such as substratum, bathymetry, and near bed hydrodynamics are important in structuring benthic habitat and are useful correlates to their geographic distribution (Warwick and Uncles 1980; Rosenberg 1995; Freeman 2001; Freeman and Rogers 2003). As with any rocky shore organism, *O. esmarki*'s occurrence is governed by the availability of suitable habitat. The presence of smaller-grained, coarse sand under-rock sediments significantly correlated with the presence of *O. esmarki*, and the lack of these sediments correlated with *O. esmarki*'s absence. At all eight of the field sites where fine sand was the primary substrate type, *O. esmarki* was not present. This is likely due to anoxic conditions which were observed in the field concurrently with fine sand. However, measurements of under-rock substrate are biased because sampling sites were preselected for substrate suitability and not randomized.

Near-shore water conditions are also an important factor influencing *O. esmarki*'s occurrence. Although dissolved oxygen and salinity are not statistically significant predictors for *O. esmarki*'s occurrence, water temperature is. Water temperatures throughout *O. esmarki*'s geographic range (Quatsino Sound, Vancouver Island, to San Lorenzo Channel, Mexico) were found to range from 8.1°C to 24.4°C. Water temperatures where *O. esmarki* was located in the field (Santa Cruz, California to Bahia Asuncion, Baja California Sur) range from 11.7°C to 20.6°C. However, these temperatures were measured at each site only once and do not account for seasonal or long-term variation. Lower water temperatures within its range predict *O. esmarki*'s absence, while higher temperatures predict its presence. Inasmuch as individuals of *O. esmarki* have been collected in locations with water temperatures above and below this temperature range near the northern and southern range edges, therefore the species has possibly evolved greater tolerances to higher temperatures, similar to those seen in *A. squamata* (Alva and Vadon 1989). Further research on populations at or near the fringes of the species' range and on *O. esmarki*'s tolerance to temperature should test this hypothesis.

ENVIRONMENTAL CORRELATES AND ABUNDANCE.— A consideration of the eight sites where abundances are greatest (> 6 individuals/m^2) reveals information about ideal substrate and water chemistry. Large *O. esmarki* abundances correlate with coarse sand as primary under-rock substrate, salinity ranging from 32.8 to 33.4 ppt, and water temperature ranging from 15.2 to 16.8°C. These new data on *O. esmarki*'s ideal habitat preferences could be used to predict the brittle star's response to climate change (Rivadeneira and Fernandez 2005). This information can also be used to delineate potential geographic extent, make comparisons between other ophiuroid and echinoderm habitat preferences, as well as assess *O. esmarki*'s sensitivity to habitat change (Freeman and Rogers 2003).

CONCLUSIONS

This study documents a range extension for *O. esmarki* that illustrates the utility of previously unpublished museum records to document more completely species ranges, especially for understudied marine invertebrates such as ophiuroids. The most substantive conclusions from this research are (1) *O. esmarki* abundances are higher in the intertidal than the subtidal, and (2) populations exhibit the abundant center distribution. The implication is that these abundance and distribution patterns suggest that the California province, range cores, and the intertidal zone may be ecologically important habitats for *O. esmarki* and similar ophiuroids. This study also presents information on ideal under-rock substrate and water temperatures that help refine the description of the ideal *O. esmarki* habitat. This adds to the body of literature on ophiuroid distribution patterns, and may be especially applicable to conservation purposes requiring information on geographic range and distribution, habitat preferences and potential *O. esmarki* sensitivity to climate change and anthropogenic impacts in near shore marine waters.

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Appendix I

Ophioplocus esmarki museum records from the Pacific Coast from 1874 to 1997

One hundred and seven previously unpublished *O. esmarki* records from the Pacific Coast from 1874 to 1997 from five museum collections: California Academy of Sciences (CAS), Los Angeles County Museum of Natural History (LACM), National Museum of Natural History (USNM), Scripps Institution of Oceanography (SIO), and Royal British Columbia Museum (RBCM). Locality data were taken from specimen labels, catalogs, and unpublished manuscripts. In the table, sites are ordered from north to south. *Ophioplocus esmarki*'s northern most record is at Quatsino Sound, Vancouver Island, whereas the southern most record is from La Playita Beach, Mexico.

Research Site	# of *O. esmarki*	*Depth*	*Museum*	*Cat. #*	*Date*	*Collector*
Quatsino Sound, BC	4	15 m	RBCM	180-52	30 Jun 1980	P. Lambert, B. Emerson
Friday Harbor, WA	1	Intertidal	CAS	111494	1918	Oldroyd
N. Pacific Ocean, CA	3	N/A	USNM	27234	15 March 1891	N/A
N. Pacific Ocean, CA	2	N/A	USNM	E23669	22 Sep 1918	W. Schmitt
N. Pacific Ocean, CA	1	N/A	USNM	E53134	26 Jun 1962	J. McLean
N. Pacific Ocean, CA	1	N/A	USNM	E29247	N/A	H.Kirby
N. Pacific Ocean, CA	1	N/A	USNM	18721	N/A	H. Lowe
N. Pacific Ocean, CA	11	N/A	USNM	26642	N/A	H. Hemphill
Mendocino, CA	2	6 m	CAS	103511	July 1965	T.Chess
Point Arena, CA	N/A	15 m	CAS	122282	20 Sep 1971	B. Laurent
Tomales Point, CA	N/A	N/A	LACM	N/A	10 Jun 1941	N/A
Farallon Isl., CA	3	N/A	CAS	4514	4 Apr 1977	C. Chaffee, B. Bowman
Farallon Isl., CA	1	Intertidal	CAS	N/A	6 Aug 1976	D. Lindberg
Moss Beach, CA	1	N/A	CAS	N/A	29 Jan 1964	E.W. Kirshbaum
Monterey Bay, CA	1	N/A	CAS	104189	N/A	E. Ricketts
Pacific Grove, CA	1	N/A	CAS	104623	4 Jul 1966	R. Setzer
Pacific Grove, CA	4	N/A	CAS	104677	17 May 1915	N/A
Pacific Grove, CA	1	N/A	CAS	104830	4 Jul 1966	R. Setzer
Pacific Grove, CA	3	N/A	CAS	111492	N/A	N/A
Pacific Grove, CA	1	N/A	CAS	121206	4 Jul 1966	R. Setzer
Point Piños, CA	1	Subtidal	CAS	104801	5 Aug 1971	J.E. Sutton
Pescadero Pt., CA	7	N/A	CAS	111491	8 Jul 1925	N/A
Malpaso Creek, CA	1	6–12 m	CAS	108601	22 Jul 1972	J.E. Sutton
Pescadero Pt., CA	3	N/A	CAS	111493	2 Mar 1931	G.E. MacGinitie
Hopkins Marine, CA	N/A	N/A	LACM	N/A	18 Jul 1952	N/A
Point Piños, CA	3	N/A	CAS	6194	22 Jul 1948	E. Friedman
Monterey Bay, CA	1	N/A	CAS	N/A	Jun2 1916	W.K. Fisher
Stillwater Cove, CA	15–20	N/A	LACM	N/A	14 May 1992	A. Summers
Piedras Blancas, CA	1	Intertidal	CAS	108794	22 Jun 1978	Bowman, Chaffee, Drake and Weitbrecht
Diablo Canyon, CA	1	N/A	CAS	122505	11 Aug 1976	D. Gotshall, CF&G
Diablo Canyon, CA	N/A	Intertidal	LACM	97.42-3	22 Jun 1997	G. Hendler
Diablo Canyon, CA	N/A	Intertidal	LACM	97.41-7	22 Jun 1997	G. Hendler
Point Sal, CA	N/A	N/A	LACM	ech 632	N/A	N/A
Coal Oil Point, CA	N/A	Intertidal	LACM	239.12	16 Feb 1970	F. Ziesenhenne
San Miguel Isl., CA	N/A	16 m	LACM	hgk 91-7	15 Oct 1991	H.G. Kuck, C. Meyer
Santa Cruz Isl., CA	2	N/A	CAS	104678	N/A	A.E. Noble
Santa Cruz Isl., CA	N/A	N/A	LACM	239.1	29 Oct 1940	N/A
Santa Cruz Isl., CA	N/A	N/A	LACM	239.1	29 Oct 1940	N/A
Santa Cruz Isl., CA	N/A	N/A	LACM	1189.4	29 Oct 1940	N/A
Santa Cruz Isl., CA	N/A	N/A	LACM	1189-40	29 Oct 1940	N/A

Research Site	# of *O. esmarki*	*Depth*	*Museum*	*Cat. #*	*Date*	*Collector*
Catalina Isl., CA	N/A	12 m	LACM	N/A	16 Oct 1988	R.A. Ronson
Catalina Isl., CA	N/A	4.6 m	LACM	N/A	25 Apr 1992	G. Hendler
Catalina Isl., CA	N/A	9 m	LACM	89-230.1	3 Mar 1989	N/A
Catalina Isl., CA	N/A	N/A	LACM	ech 630	N/A	G. Hendler
Gulf of Catalina, CA	2	73 m	USNM	12644	1874	W. Dall
Gulf of Catalina, CA	1	55–73m	USNM	12732	1874	W. Dall
Gulf of Catalina, CA	2	N/A	USNM	12930	N/A	W. Dall
Gulf of Catalina, CA	1	N/A	USNM	4290	N/A	N/A
Catalina Isl., CA	N/A	Subtidal	LACM	123.3	23 Jul 1993	R. Sherlock
Catalina Isl., CA	1	N/A	CAS	104877	1 Nov 1972	A.J. Ferreira
Catalina Isl., CA	1	N/A	CAS	108795	28 Jul 1964	B. Marquardt
Venice, CA	N/A	N/A	LACM	239.18	N/A	N/A
Redondo Beach, CA	N/A	Intertidal	LACM	239.13	8 Feb 1947	F. Ziesenhenne
Palos Verdes, CA	1	N/A	CAS	N/A	N/A	N/A
Point Fermin, CA	1	N/A	CAS	N/A	21 Apr 1913	N/A
Point Fermin, CA	N/A	Intertidal	LACM	93-10.3	9 Jan 1993	G. Hendler
Southern CA	N/A	N/A	LACM	ech 629	N/A	G. Hendler
Point Vicente, CA	N/A	N/A	LACM	ech 617	N/A	N/A
Point Vicente, CA	N/A	N/A	LACM	ech 618	N/A	N/A
Point Vicente, CA	N/A	N/A	LACM	ech 624	N/A	N/A
San Pedro, CA	N/A	N/A	LACM	ech 628	N/A	N/A
Point Fermin, CA	N/A	Intertidal	LACM	604	1 Nov 1928	A. Hancock
Portuguese Bend, CA	N/A	N/A	LACM	1013-39	10 Nov 1939	A. Hancock
Portuguese Bend, CA	N/A	Intertidal	LACM	N/A	13 Feb 1942	N/A
Portuguese Bend, CA	N/A	Intertidal	LACM	N/A	26 Jun 1914	N/A
Portuguese Bend and Redondo, CA	N/A	N/A	LACM	907-38	9 Dec 1938	N/A
Long Beach, CA	N/A	N/A	LACM	N/A	N/A	N/A
Corona Del Mar, CA	N/A	N/A	LACM	96-1.5	17 Feb 1996	G. Hendler and F. Nishida
Laguna Beach, CA	N/A	N/A	LACM	ech 647	N/A	N/A
Laguna Beach, CA	N/A	N/A	LACM	N/A	N/A	G. Hendler
Newport Bay, CA	3	N/A	CAS	111490	Jan Feb 1930	G.E. MacGinitie
Dana Point, CA	N/A	N/A	LACM	200.1	1 Oct 1936	G. Ranokoff
San Clemente Is., CA	1	Intertidal	LACM	1025-39	25 Nov 1939	A. Hancock
Point Loma, CA	N/A	N/A	SIO	E-587	26 May 1966	Taylor-Heese
Point Loma, CA	2	N/A	CAS	104622	31 Jul 1916	C.L. Hubbs
Point Loma, CA	N/A	N/A	LACM	39.275.2	26 Dec 1939	R. Morrison
La Jolla, CA	N/A	15 m	SIO	E-1156	17 Nov 1958	R. Kiwala
La Jolla, CA	N/A	12–14 m	SIO	E-803	25 Sep 1959	C.L. Hubbs
La Jolla, CA	N/A	N/A	SIO	E-227	19 Nov 1915	N/A
La Jolla, CA	1	N/A	CAS	15427	April 1942	E. Ricketts

Research Site	# of *O. esmarki*	*Depth*	*Museum*	*Cat. #*	*Date*	*Collector*
Bird Rock, CA	N/A	N/A	LACM	42-64.1	Oct 1942	R. J Berman
False Point, CA	N/A	Intertidal	LACM	96-2.2	Feb 1996	G. Hendler and F. Nishida
False Point, CA	3	Intertidal	CAS	Na	Jun 1974	A. Muscat
San Diego, CA	1	N/A	CAS	Na	N/A	N/A
La Jolla , CA	1	N/A	CAS	JBS 32	1947	T. and A. Stephenson
False Point, CA	7	N/A	LACM	N/A	19 Mar 1992	M.E. Bergen
False Point, CA	1	N/A	LACM	N/A	27 Apr 1992	M.E. Bergen
Point Loma, CA	N/A	N/A	SIO	E-2186	31 Oct 1955	P. Johnson
Point Loma, CA	N/A	Intertidal	LACM	239.15	26 Dec 1939	F. Ziesenhenne
Baja CA, MX	1	N/A	USNM	E 26873	N/A	R. Smith
Ensenada, MX	N/A	Intertidal	LACM	N/A	29 Nov 1963	J.H. McLean, J.H.Dearborn
Ensenada, MX	12	N/A	CAS	15427	Apr 1942	E. Ricketts
Todos Santos, MX	4	N/A	CAS	N/A	20 Dec 1930	G.E. MacGinite
Todos Santos, MX	N/A	N/A	LACM	824	Dec 1927	F. Ziesenhenne
San Martin, MX	5	N/A	CAS	2949	20 Feb 1975	N/A
Guadalupe Is., MX	10	Subtidal	CAS	121208	18 Mar 1932	T. Crocker
San Bentio Is., MX	N/A	Intertidal	SIO	E-1880	26 May 1971	R/V Agassiz
E. San Benito Is., MX	N/A	Intertidal	LACM	33	4 Jun 1933	A. Hancock
E. San Benito Is., MX	N/A	N/A	LACM	N/A	4 Jun 1943	A. Hancock
Bahia Tortugas, MX	N/A	Intertidal	LACM	N/A	24 Feb 1942	J. Garth
Bahia Tortugas and Bahia Asunción, MX	N/A	2–4 m	SIO	E-1845	4–6 Aug 1980	M. Tegner
San Bartolome, MX	N/A	Intertidal	LACM	239.17	12 Feb 1954	N/A
San Bartolome, MX	N/A	Intertidal	LACM	239.19	25 Apr 1961	N/A
Malarrimo, MX	1	Intertidal	LACM	239.16	17 Apr 1951	F. Ziesenhenne
San Lorenzo Ch., MX	N/A	N/A	LACM	607.36	21 Mar 1936	N/A
Thurloe Bay, MX	N/A	Intertidal	LACM	283.34	9 Mar 1939	A. Hancock
La Playita, MX	N/A	Intertidal	LACM	239.11	8 Apr 1950	F. Ziesenhenne

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Anisotes (Acanthaceae) in Madagascar

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Two species of *Anisotes* (Acanthaceae: Justicieae) are recognized from Madagascar. *Anisotes madagascariensis* is endemic to sandy, coastal regions of southern Madagascar. New morphological, distributional, and ecological data are presented for this species. A newly described species, *A. divaricatus*, is known only from calcareous, rocky substrates near Lake Tsimanampetsotsa in southwestern Madagascar. Major morphological distinctions between *A. divaricatus* and *A. madagascariensis* include: habit (divaricate branches vs. ascendant branches); length (5–11 vs. 14–45 mm long) and shape (obcordate to obdeltate vs. broadly ovate to elliptic) of leaf blades; corolla form (corolla tube:corolla 0.46–0.56 vs. 0.23–0.38; lower lip not spirally coiled vs. spirally coiled); and capsule pubescence (lacking trichomes vs. trichomes present). Images of flowers and pollen, morphological descriptions, and mapped distributions are provided for both species.

Nineteen species occurring from tropical and southern Africa to Madagascar and tropical Arabia were recognized in the most recent revision of *Anisotes* (Baden 1981). The genus has traditionally been included in subfamily Acanthoideae, tribe Justicieae based on its 2-lipped, "imbricate" (presumably ascending cochlear aestivation in *Anisotes* and its relatives) corollas with bithecous stamens. Baden (1981) and others have noted that generic delimitation in Justicieae is problematic. Indeed, *Anisotes* does not appear well circumscribed in the tribe based on either macromorphological or palynological characters. No morphological synapomorphies can be identified for it, and it is reasonable to suppose that it is not necessarily monophyletic. Baden (1981) did not identify a probable closest relative for *Anisotes*, but he noted some morphological similarities (especially corollas) between *Anisotes* and *Metarungia* Baden (as *Macrorungia C.B. Clarke*). He distinguished them by the presence of elastically separating placentas (with attached retinacula) in capsules of the latter genus; placentas/retinacula remain attached to the inner surface of capsules in *Anisotes*.

A single species of *Anisotes* has been reported from Madagascar, *A. madagascariensis*; however, Lindau (1898) described *Symplectochilus madagascariensis* Lindau from Madagascar, and *Symplectochilus* is now treated as congeneric with *Anisotes*. Baden (1981) indicated that the taxonomic position of *S. madagascariensis* "remains doubtful due to inadequate type material." Indeed, the type (Antsiranana: Bay of Diego Suarez, forest, 1833, *Goudot s.n.* at G, photo!) of this name was collected in a different habitat far from the known distribution of *A. madagascariensis*, does not represent the same taxon as the type of *A. madagascariensis*, and does not necessarily pertain to the genus *Anisotes*. Additional plants resembling *Anisotes* have been reported (e.g., Gautier

2002) from other regions of the island; Benoist annotated specimens at P with names of several new species and new combinations for plants from Madagascar and the Comoros, but he did not publish them; and several herbarium specimens of unknown taxa (e.g., *Phillipson 1904* at CAS from Mahajanga, *Bosser 5917* at TAN from Montagne d'Ambre) show affinities to *Anisotes*. This summary of *Anisotes* in Madagascar incorporates information not known to or reported by Baden (1981) for *A. madagascariensis*, such as descriptions of capsules and seeds, fruiting phenology, detailed distributional data, chromosome number, and phylogenetic position based on molecular sequence data. In addition, a second distinctive species from southwestern Madagascar is newly described and compared to *A. madagascariensis*.

Recent molecular phylogenetic studies that included Old World "justicioids" (McDade et al. 2000; Kiel et al. 2006) reveal that *Anisotes* is closely related to several species of *Justicia* from the Old World (e.g., *J. adhatoda* L., *J. anagalloides* (Nees) T. Anderson, and *J. campylostemon* (Nees) T. Anderson) and *Duvernoia aconitiflora* A. Meeuse. Based on limited sampling of *Anisotes*, Kiel et al. (2006) showed that the African species *A. rogersii* S. Moore is sister to *J. adhatoda*, and that this pair is sister to *A. madagascariensis* in a strongly supported clade. Additional molecular markers as well as more samples of *Anisotes* and Old World "justicioids" will be necessary to test monophyly for the 19 species treated by Baden (1981) and to resolve possible phylogenetic relationships among them, but there appears to be little doubt that *A. madagascariensis* is closely related to African species of *Anisotes*. *Metarungia* appears to be monophyletic (based on a sampling of two species; Kiel et al. 2006) and basal to a larger clade that includes *Anisotes*.

Daniel (2006) reported a chromosome count of $n = 17$ for *Anisotes madagascariensis*, the first number reported for the genus. Chromosome numbers of $n = 17$ have been reported elsewhere among Old World "justicioids" in two species of *Justicia* (Daniel and Chuang 1998; Daniel 2000; Daniel et al. 2000), in *Duvernoia aconitiflora* (Daniel et al. 2000), and in *Rungia repens* Nees (Subramanian and Govindarajan 1980; however, most counts for this species are $n = 10$: Narayanan 1951; Ellis 1962; Ranganath 1981; Krishnappa and Ranganath 1982; Saggoo 1983). Counts of $n = 17$ are well established in both *J. betonica* L. of section *Betonica* and *J. adhatoda* of section *Vasica*. The common chromosome number shared by *A. madagascariensis*, *J. adhatoda*, and *D. aconitiflora* undoubtedly reflects their close phylogenetic relationships as revealed by molecular markers (Kiel et al. 2006). In spite of counts of $n = 17$ in *J. betonica* and *Rungia repens*, neither the former species nor the latter genus appear especially closely related to the clade consisting of *Anisotes* and *J. adhatoda* based on molecular phylogenies (McDade et al. 2000; Kiel et al. 2006). The sole chromosome count for *Metarungia*, posited as a potentially close relative of *Anisotes* by Baden (1981), is $n = 14$ (Daniel et al. 2000).

Baden (1981) described palynological variation among species of *Anisotes* based on sculptural characteristics. Differences consist primarily of the number and types of apertures with grains varying from 2–4-porate with the apertures flanked by two or four rows of insulae in a "trema area" to 2–3-colporate with the apertures flanked by pseudocolpi. Baden (1981) used these differences to help delimit six sections of *Anisotes*. Pollen of the newly described species from Madagascar, *A. divaricatus*, resembles that of *A. madagascariensis* in size, aperture type and number, and exine microsculpturing (i.e., bireticulate). Pollen of each species is characterized below.

Anisotes Nees

TYPE.— *A. trisulcus* (Forssk.) Nees

Himantochilus T. Anders. ex Benth. **Type.**— *H. sessiliflorus* T. Anders.
Symplectochilus Lindau **Type.**— *S. formosissimus* (Klotzsch) Lindau

Suffrutescent perennials, shrubs, or small trees. Leaves deciduous or evergreen, opposite, sessile to petiolate, margin entire to crenate. Inflorescences of axillary or terminal spikes, racemes, or thyrses; bracts opposite; bracteoles present or absent; dichasia 1–3-flowered, sessile to pedunculate. Flowers sessile to pedicellate; calyx 5-lobed; corolla reddish, purple, orange, or yellowish, tube ± cylindric to ampliate distally, limb 2-labiate, upper lip convavo-convex, usually ± arched, entire to 2-fid at apex, internally rugulate, lower lip deeply 3-lobed, straightforwardly splayed, recoiled, or spirally twisted, aestivation presumably ascending cochlear (lower lip outermost in bud, but lobes of lower lip either not evident or not overlapping in buds observed). Stamens 2, inserted near apex of corolla tube, exserted from corolla tube but not extending beyond upper lip (under which they are ± enclosed), anthers 2-thecous, thecae parallel to ± oblique, subequally to unequally inserted, ± equal to unequal in size, basal appendage present or absent; staminodes absent; pollen 2-, 3-, or 4-aperturate, colporate/pseudocolpate or porate (to colporate) in trema regions studded with circular insulae. Stigma 2-lobed or lobes obscure. Capsule stipitate, retinacula remaining attached to inner wall of mature capsule. Seeds 4 (or fewer by abortion), lenticular.

Key to Species of *Anisotes* in Madagascar

1a. Leaf blades broadly ovate to broadly elliptic to elliptic to ovate-elliptic, 14–45 mm long, 10–38 mm wide, 1.1–2.7 times longer than wide, rounded (to emarginate) at apex; calyx 2–3.5 mm long, margin of lobes ± densely ciliate; corolla with the internal surface conspicuously lighter colored than the external surface, corolla tube:corolla = 0.23–0.38, corolla tube 9–15 mm long, upper lip 20–35 mm long and distally whitish to pinkish along the margin, lower lip spirally coiled, 18–28 mm long, lobes 12–14 mm long; stamens 26–33 mm long; capsule pubescent with flexuose to antrorse eglandular trichomes 0.05–0.1 mm long; growing on sandy flats and dunes ..... *A. madagascariensis*

1b. Leaf blades broadly obovate to subcircular to obcordate to obdeltate to oblate, 5–14 mm long, 4.5–14.3 mm wide, 0.7–1.3 times longer than wide, emarginate to truncate at apex; calyx 1.3–2.7 mm long, margin of lobes eciliate to sparsely ciliate; corolla with the internal surface not conspicuously lighter in color than the external surface, corolla tube:corolla = 0.46–0.56, corolla tube 14–20 mm long, upper lip (11-) 14–18 mm long, lacking a pale margin distally, lower lip recurved to reflexed (not spirally coiled), 11–19 mm long, lobes linear, 8–12 mm long; stamens 15–18.5 mm long; capsule ± scurfy but lacking noticeable eglandular trichomes; growing on limestone ..... *A. divaricatus*

***Anisotes madagascariensis* R. Ben., Bull. Soc. Bot. France 76:1036. 1929.**

Type.— Madagascar: **Toliara**: dunes, rives du Lac Mananpetsa [Tsimanampetsotsa], coté Mahafaly, June 1910, *H. Perrier de la Bâthie 9494* (lectotype, designated by Baden in 1981: P!; isolectotype: P!). Figure 1c.

Shrubs to 2 m tall; older branches (± divaricate to) ascending usually at angles of 40–70°. Young stems quadrate-ridged, densely and evenly pubescent with (flexuose to) antrorse to antrorsely appressed eglandular trichomes 0.2–0.4 mm long, pubescence resulting in a grayish green coloration. Leaves coriaceous to subsucculent, petiolate, petioles to 12 mm long, blades broadly ovate to broadly elliptic to elliptic to ovate-elliptic, 14–45 mm long, 10–38 mm wide, 1.1–2.7 times longer than wide, acute at base, rounded (to emarginate) at apex, venation obscure, surfaces densely and evenly pubescent with cauline type trichomes, pubescence resulting in a grayish green coloration. Inflorescence of ± congested, axillary (usually only in axils of distalmost 1–3 pairs of

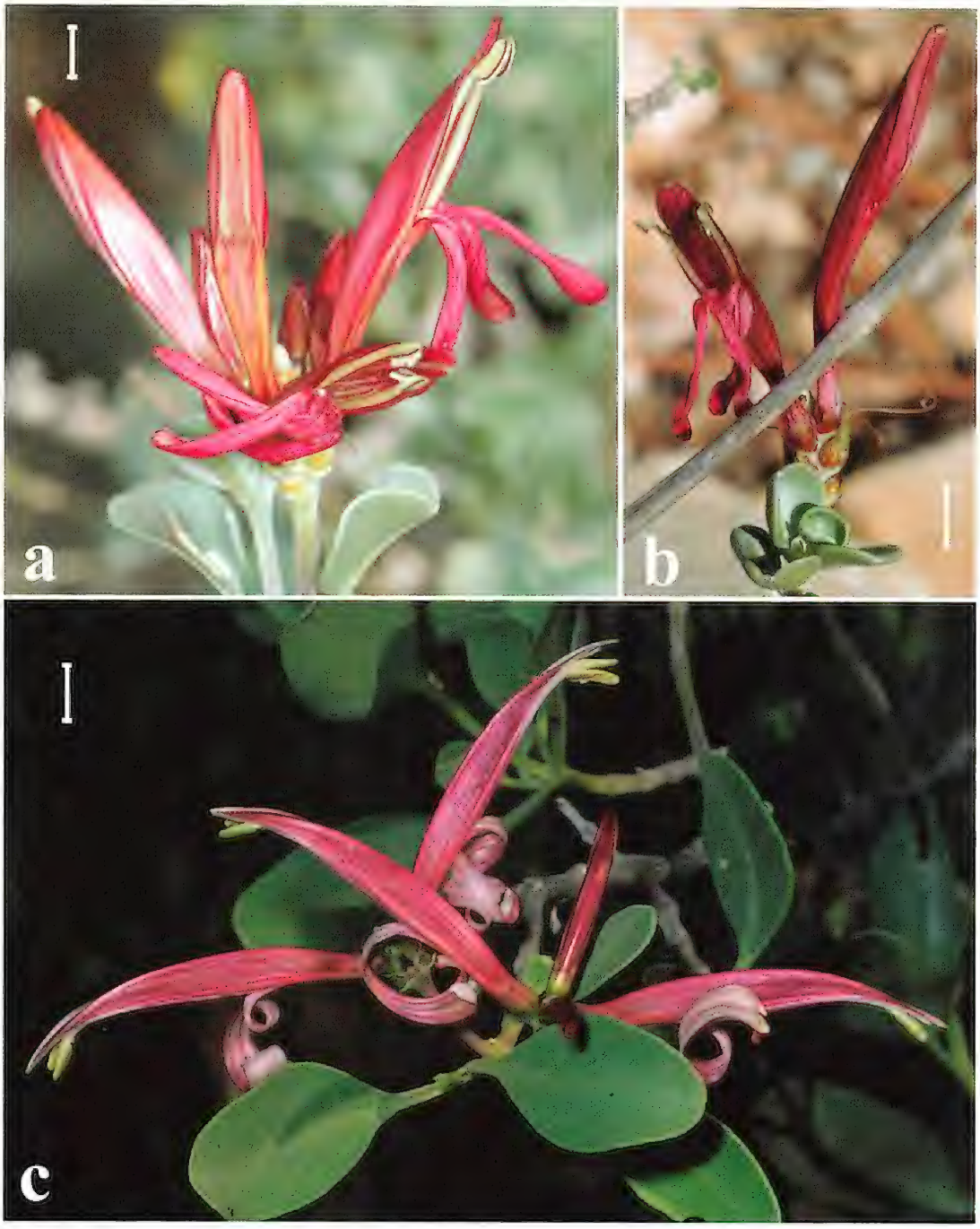

FIGURE 1. Flowers of *Anisotes divaricatus* (a–b) and *A. madagascariensis* (c). a. *Almeda 9237*, scale = 4 mm, photo by F. Almeda. b. *Almeda 9237*, scale = 5 mm, photo by H. Mally. c. *Almeda 7705*, scale = 8 mm, photo by F. Almeda.

leaves) and/or terminal, pedunculate spikes, peduncles to 24 mm long, rachis densely pubescent like young stem, internodes usually very short or inconspicuous. Bracts opposite, all fertile, subtending a single flower, broadly triangular, 1–2 mm long, 1.5–2.2 mm wide, abaxial surface densely pubescent with antrorse eglandular trichomes 0.1–0.2 mm long. Bracteoles absent. Flowers sessile (to subsessile), usually more than 2 per spike. Calyx 5-lobed, 2–3.5 mm long, tube ca. equal to lobes (i.e., slightly longer to slightly shorter than lobes), lobes ovate to triangular, 0.6–1.8 mm long, 0.9–1.1 mm wide, 0.30–0.69 times as long as calyx, abaxial surface nearly glabrous to sparsely pubescent (especially near apex) with antrorse to antrorsely appressed eglandular trichomes 0.05–0.1 mm long, margin ± densely ciliate with flexuose to antrorse eglandular trichomes. Corolla maroon to dull red to pink-brown externally, pinkish to whitish internally, externally glabrous, (30–) 33–47 mm long, tube proximally cylindric, ± gradually expanded distally, 9–15 mm long, 3–4 mm in diameter near midpoint, corolla tube:corolla = 0.23–0.38, upper lip 20–35 mm long, internally rugulate, entire at apex, distal portion with whitish to pinkish margin, lower lip spirally coiled, 18–28 mm long, lobes 12–14 mm long, 1.6–3.2 mm wide. Stamens 26–33 mm long, inserted near apex of corolla tube, exserted from mouth of corolla but not surpassing upper lip, filaments whitish, glabrous, thecae maroon, unequal in size (distal theca longer, 3.2–4 mm long, proximal theca shorter, 2.4–3.5 mm long), unequally inserted (overlapping by 1–1.6 mm), glabrous, lacking basal appendages (or proximal theca with an inconspicuous appendage to 0.1 mm long); pollen 62.5–74 µm polar diameter (P), 32.5–42.5 µm equatorial diameter (E), P:E = 1.52–1.90. Style 29–36 mm long, glabrous, stigma lobes obscure or 0.2 mm long. Nectar disk cupuliform and often visible between calyx lobes. Capsule 18–24 mm long, externally pubescent with flexuose to antrorse eglandular trichomes 0.05–0.1 mm long, stipe 9–11 mm long, head ellipsoid to obovoid. Seeds 4, discoid, (3.2–) 4.5–5 mm long, (3.6–) 4.1–5 mm wide, surfaces minutely papillose or rugose and shiny, margin ± swollen and smooth. (n = 17, Daniel 2006).

Floral Phenology.— Flowering: throughout the year; fruiting: May, August–October.

Distribution and habitats.— Endemic to southern Madagascar; plants occur on dunes and in sandy flats in regions of spiny forest (with *Didierea madagascariensis* and *Euphorbia stenoclada*) generally along the coast of the Mozambique Channel at elevations from sea level to 20 m (Fig. 2). Two apparently wild collections were made in coastal regions of the Indian Ocean near Ambovombe Androy, well to the east of Cap Sainte Marie and about 225 km disjunct from the nearest known locale of the species at Itampolo on the west coast (*Allorge 428* and *Decary 2729*—not seen, but cited among the syntypes of *A. madagascariensis* in the protologue). The coastal region between Itampolo and Ambovombe remains poorly collected, and it is possible that the range of the species is more extensive than presently known in coastal regions of southern Madagascar. Label data of *Peltier & Peltier 5858* indicate that plants of *A. madagascariensis* were collected at or near Tongobory. This town on the Onilahy River is about 55 km inland from the Mozambique Channel. Based on collection records, the Peltiers traveled from St. Augustin at the mouth of the Onilahy River to Tongobory on either 31 March 1966 or 1 April 1966. It remains unknown whether the species occurs naturally near Tongobory or whether it was collected nearer to the coast than indicated by the label data. Because of this uncertainty, *Peltier & Peltier 5858* is not indicated on the map.

Local names.—"Berava," "beravo" (*Koechlin 25*); "hazontsohy" (*Ravelonanahary 3286-RN*); "hazontsoy" (*Ravelonanahary 2787-RN, 3926-RN, 4287-RN*); "hazontsohy lahy" (*Ravelonanahary 4159-RN*); "voamany" (*Koechlin 1*); "voamamy" (*Koechlin 2*).

Muller et al. (1989) described and figured pollen of *A. madagascariensis* (from *Humbert & Swingle 5295*) as 3-colporate and 6-pseudocolpate. Baden (1981; based on *Perrier de la Bâthie 9494*) described it as 3-porate with a trema area having reticulate bands (i.e., 3-colporate, 6-pseudo-

colpate). Baden (1981) treated species of *Anisotes* in six sections based primarily on characters of the inflorescence and pollen. *Anisotes madagascariensis* was placed into section *Spiciflori* based on its inflorescence of spikes, non-reticulate nerved bracts, "large" corolla:tube ratio, and 3-aperturate pollen with apertures flanked by pseudocolpi (Fig. 3). The only other species placed into this section by Baden (1981), *A. formosissimus* (Klotzsch) Milne-Redhead, occurs in Mozambique, Zimbabwe, and Malawi in southeastern Africa. It differs from *A. madagascariensis* by its longer spikes, bracts, and calyx; glabrate leaves; and bracteoles, which are present.

Although Baden (1981) cited only 5 collections of this species, plants are frequent along the southwestern coast of Madagascar. Because plants often occur in disturbed habitats, this attractive species is well suited for horticultural use in local landscaping. Although pollinators have not been documented for *A. madagascariensis*, Long-billed Green Sunbirds (*Nectarinia notata*) were observed visiting flowers of *Daniel & Butterwick 6736* in November.

Cours 4643 at P consists of three sheets, two of which bear the label "Itinéraire Didy à Brickaville." This is presumed to be a labeling error because Didy is a forest on the eastern escarpment at about 1000 m elevation, and Brickaville, the old name for Ampasimanolotra, is on the central-eastern coast of Madagascar; these locales are very far from the others and have different habitats. *Cours 4643* differs from other collections by having spikes 2-flowered and flowers subsessile (i.e., borne on pedicels to 1 mm long); in other respects, it resembles most other collections.

Additional specimens examined.— Madagascar: **Toliara**: Ambovombe, chemin 100 m avant l'océan, 11 September 1992 (flr), *L. Allorge 428* (P); just N of Itampolo on Mozambique Channel, 1 April 1996 (flr), *F. Almeda 7705* (CAS); Itampolo, 13 May 1951 (flr, frt), *J. Bosser 78* (P, TAN); Efoetsy, 12 May 1951 (flr), *J. Bosser 116* (P), *126* (TAN); environs de Tulear, November 1956 (flr), *J. Bosser 10598* (P, TAN); au nord du Fiherenana, 27 June 1958 (flr), *R. Capuron 18623-SF* (P); "Itinéraire Didy à Brickaville" [locality uncertain — see discussion], *M. Cours 4643* (P); 12 km N of Tulear, 5 February 1975 (flr), *T. Croat 30821* (MO, P); ca. 5 km S of Hotel Lakana Vezo in Ifaty toward Toliara (ca. 20 km N of Toliara along coast), ca. 0 m, 5 November 1993 (flr), *T. Daniel & M. Butterwick 6736* (CAS); ca. 28 km N of Toliara, just N of Ifaty along road to Ankaraobato, 23°6′S, 43°36.5′E, 5 m, 9 October 2003 (flr, frt), *T. Daniel et al. 10422* (CAS, K, MO, P, PH, TAN); District Betioky, Anakao, 21 October 1940 (flr), *R. Decary 16077* (MO, P); environs terrain d'aviation Tuléar, *J. DeQuaire 27548* (P); Itampolo, 1945 (flr), *A.-M. Homolle 1650* (P); environs de Tuléar, delta du Fiherenana, 6

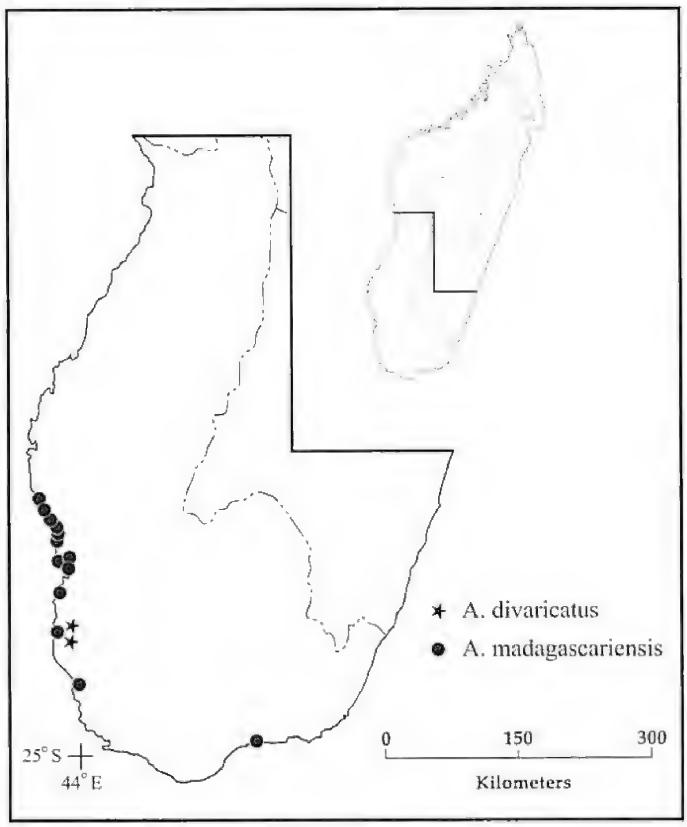

FIGURE 2. Map of southwestern Madagascar showing distributions of *A. divaricatus* and *A. madagascariensis*.

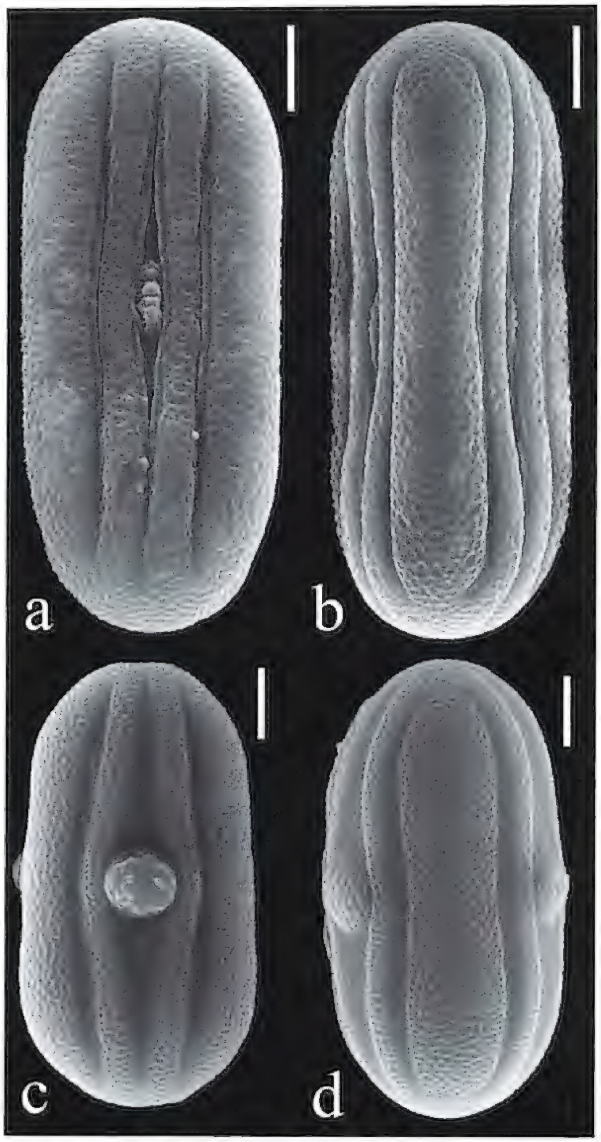

FIGURE 3. Pollen of *Anisotes divaricatus* (a, b; *Almeda 9237*) and *A. madagascariensis* (c, d; *Daniel et al. 10422*). a. apertural view. b. interapertural view. c. apertural view. d. interapertural view. Scale lines = 10 µm.

August 1928 (flr, frt), *H. Humbert & C. Swingle 5164* (P, TAN), 14–26 September 1924 (flr), *H. Humbert et al. 2425* (P); du Lac Manampetsotsa au delta de La Linta (Cote Sud-Ouest), 1–10 m, 17–24 August 1928 (flr), *H. Humbert & C. Swingle 5295* (P, UC); Anakao, 3 September 1967 (flr), *B. Koechlin 1* (P); Manombo, Anjevo, 4 November 1967 (flr), *B. Koechlin 2* (P); Songeritelo, 23 September 1967 (sterile), *B. Koechlin 25* (P); environs de Tuléar, route de Manombo, 3 November 1960 (flr), *J. Leandri & R. Jean de Dieu 3626* (P), *3634* (MO, P); 21 km N of Ifaty on track from Manambo to Tsifota, near Fiserenamasay, 22°48′S, 43°18′E, 0 m, 4 August 1993 (flr), *B. Lewis et al. 515* (TAN); Tsivonoa N., 11 September 1961 (flr), *J. Peltier & M. Peltier 3384* (P, TAN); Tongobory, 1 April 1966 (flr), *J. Peltier & M. Peltier 5858* (P); environs de Tulear, August 1919 (flr, frt), *H. Perrier de la Bâthie 19811* (P); 20 km N of Tulear, near resort of Mora Mora, Ifaty ["Italy"], 23°11′S, 43°07′E, 10 m, 7 May 1987 (flr), *P. Phillipson 1776* (CAS, MO, P, TAN); N of Itampolo, 24°41′S, 43°57′E, 10 October 1990 (flr), *P. Phillipson et al. 3739* (CAS, MO, P, TAN); Befanany, 2 August 1921 (flr), *H. Poisson 277* (P); outskirts of village of Itampolo, 24°42′S, 43°57′E, 0 m, 9 February 1990 (flr), *B. du Puy et al. MB686* (MO, P, TAN); NW of Toliara, Forest of Mikea, ca. 13 km N of mouth of Manombo River, 22°53′S, 43°24′E, 10 m, 4 December 1993 (flr), *D. du Puy et al. M691* (P, TAN); Tulear, *Raich 1097* (TAN); District Tulear, Réserves Naturelles, 22 May 1951 (flr), *L. de G. Ravelonanahary 2787-RN* (P, TAN); District Betioky, Réserves Naturelles, 31 December 1951 (flr), *L. de G. Ravelonanahary 3286-RN* (P); District Betioky, Réserves Naturelles, *L. de G. Ravelonanahary 3926-RN* (P, TAN); District Betioky, Réserves Naturelles, July 1952 (flr), *4159-RN* (P, TAN); District Tulear, Réserves Naturelles, 24 October 1952 (flr), *L. de G. Ravelonanahary 4287-RN* (P, TAN); 35 km N of Toliara along coast road, 23°04′S, 43°35′E, 20 m, 12 December 1988 (flr), *G. Schatz & J. Miller 2471* (CAS, MO, P); ca. 19 km NNW of Tulear on RN 9, ca. 2 km N of Songoritela toward Morombe, 0 m, 9 June 1991 (flr), 23°12′S, 43°37′E, *J. Zarucchi et al. 7575* (MO, TAN).

Anisotes divaricatus T.F. Daniel, Mbola, Almeda, and Phillipson, sp. nov.

TYPE.— MADAGASCAR: **Toliara**: Réserve du Lac Tsimanampetsotsa (No. 10), NW corner of reserve, 24°04′S, 43°46′E, escarpment of calcareous plateau, 50 m, 8 October 1990, *P. Phillipson et al. 3721* (holotype: CAS!; isotypes: MO, P!, TAN!). Figures 1, 4.

Frutex usque ad 1 m, ramis vetustis ± divaricatis. Folia petiolata, laminae subsucculentae, late ovatae vel subcirculares vel obcordatae vel obdeltatae vel oblatae, 5–14 × 4.5–14.3 mm, 0.7–1.3-plo longiores quam latiores, emarginatae vel truncatae ad apicem, costa solum manifesta (in pagina abaxiali). Spicae axillares, pedunculares. Bracteae triangulares vel late triangulares, 1–1.3 mm longae. Calyx 1.3–2.7 mm longus. Corolla rubra-purpurea intus, 27–40 mm longa. Capsula 13–20 mm longa, trichomatibus eglandulosis nullis. Semina 3.8–4.8 mm longa.

Scrambling to clambering or arching shrubs to 1 m; older branches ± divaricate. Young stems quadrate-ridged [similar to subhexagonal but only small valleys at corners], densely and evenly pubescent with (flexuose to) antrorse to antrorsely appressed eglandular trichomes 0.2–0.4 mm long, resulting in a grayish cast. Leaves petiolate, petioles to 5 mm long, blades subsucculent, broadly obovate to subcircular to obcordate to obdeltate to oblate, 5–14 mm long, 4.5–14.3 mm wide, 0.7–1.3 times longer than wide, acute at base, emarginate to truncate at apex, venation obscure, midvein only evident on abaxial surface, surfaces and margin ± densely and evenly pubescent with cauline type trichomes, resulting in a grayish cast. Inflorescence of ± congested, axillary (in axils of distalmost 1–3 pairs of leaves), pedunculate spikes; peduncles 2–11 mm long, rachis densely to sparsely pubescent like young stems, internodes to 1 mm long. Bracts opposite, all fertile, each subtending a single flower, triangular to broadly triangular, 1–1.3 mm long, 0.8–1.2 mm wide, abaxial surface densely pubescent with (flexuose to) antrorse to antrorsely appressed eglandular trichomes 0.1–0.2 mm long. Bracteoles absent. Flowers sessile to subsessile (i.e., pedicels to 0.3 mm long). Calyx 5-lobed, 1.3–2.7 mm long, tube shorter than lobes, lobes triangular to lanceolate to ovate to obovate, 1–1.7 mm long, 0.7–1 mm wide, 0.63–0.87 times as long as calyx, abaxial surface sparsely pubescent (especially distally) with antrorse to antrorsely appressed eglandular trichomes 0.05–0.1 mm long, margin eciliate to sparsely ciliate with flexuose to antrorse eglandular trichomes. Corolla ± concolorous, dull purple-red (maroon), or ± discolorous with the tube pink-brown (bronze colored) and only the lobes of the lower lip maroon, externally mostly glabrous (occasionally with a few flexuose to retrorse eglandular trichomes to 0.2 mm long proximally), 27–40 mm long, tube 14–20 mm long, narrow proximal portion subcylindric, 4–7 mm long, ± abruptly expanded into a funnelform throat, throat 9–14 mm long, 2.8–4 mm in diameter near midpoint, corolla tube:corolla = 0.46–0.56, upper lip (11-) 14–18 mm long, internally rugulate, entire to emarginate at apex, lacking a pale colored margin distally, lower lip recurved to reflexed, 11–19 mm long, lobes linear, 8–12 mm long, 1–4 mm wide, central lobe larger than lateral lobes. Stamens 15–18.5 mm long, inserted near apex of corolla tube, exserted from mouth of corolla but usually not surpassing upper lip (or surpassing it by up to 1 mm), filaments cream, glabrous, thecae yellow and brown, unequal in size (distal larger, 2.4–3.3 mm long; proximal shorter, 2–2.8 mm long), unequally inserted (overlapping by 0.8–1.2 mm), parallel to slightly oblique, glabrous, lacking basal appendages or proximal theca with an inconspicuous basal appendage 0.05 mm long; pollen 72 µm polar diameter (P), 28–30.5 µm equatorial diameter (E), P:E= 2.4–2.6. Style 24–32 mm long, glabrous, stigma 0.2–0.3 mm long, lobes obscure. Nectar disk asymmetric, often with a lobe-like appendage to 0.6 mm long protruding between outermost (i.e., farthest from rachis) pair of calyx lobes. Capsule 13–20 mm long, surface ± scurfy but lacking noticeable eglandular trichomes, stipe 5–8 mm long, head ovoid-ellipsoid to obovoid-ellipsoid with a slight medial constriction. Seeds 4, discoid, 3.8–4.8 mm long, 3.7–5.1 mm wide, surfaces minutely papillose or rugose, shiny, margin sometimes ± swollen and smooth.

Phenology.— Flowering: August–May; fruiting: August–October, April.

Distribution and habitat.— Endemic to southwestern Madagascar; plants occur on limestone rock (Mahafaly Plateau limestone) with spiny forest (dominated by *Alluaudia comosa*; *Commiphora* spp. including *C. humbertii*, *C. simplicifolia*, and the local endemics *C. tsimanampet-*

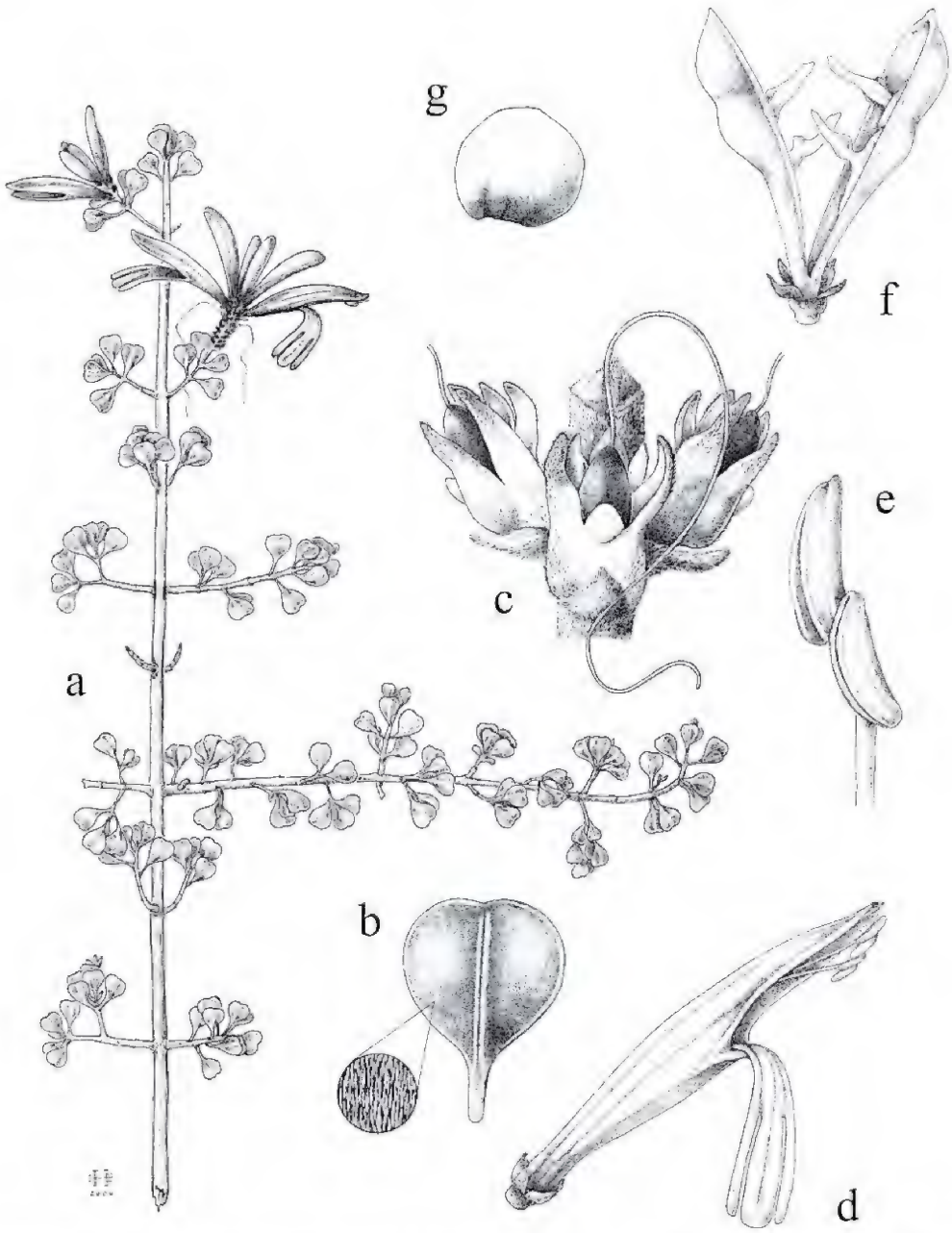

FIGURE 4. *Anisotes divaricatus*. a. Habit (*Leandri & Saboureau 4441*), × 0.5. b. Leaf (abaxial surface), × 2.1, with close-up of pubescence, × 16 (*Leandri & Saboureau 4441*). c. Inflorescence nodes with corollas removed (*Bosser 1762*), × 8. d. Flower (*Bosser 15609 & Perrier de la Bâthie 19156*), × 1.7. e. Distal portion of stamen (*Perrier de la Bâthie 19156*), × 7.8. f. Capsule (*Perrier de la Bâthie 19156*), × 3. g. Seed (*Perrier de la Bâthie 19156*), × 3.5. Drawn by Erin Hunter.

sae and *C. monstruosa*; *Delonix decaryi* and *D. floribunda*; *Adansonia rubrostipa*; *Euphorbia alluaudii* ssp. *oncoclada* and *E. tirucalli*; and *Uncarina stellulifera*) in the vicinity of Lake Tsimanampetsotsa at elevations from 22–80 m (Fig. 2).

Anisotes divaricatus is both morphologically and ecologically distinct from *A. madagascariensis*. However, based on its spicate inflorescence, bracts lacking reticulate venation, and 3-aperturate pollen (Fig. 3), *A. divaricatus* would also appear to belong to section *Spiciflori*. Like *A. madagascariensis* and unlike *A. formosissimus*, the only other species of section *Spiciflori*, *A. divaricatus* lacks bracteoles. Indeed, the two Malagasy species are the sole representatives of the genus in which these structures are not present.

Both Malagasy species occur in the vicinity of Lake Tsimanampetsotsa and the general collecting locales are sometimes identical for each (e.g., "Efoetsy" or "near Lake Tsimanampetsotsa"). In most such instances, however, plants of *A. madagascariensis* were noted to have been collected from coastal sands or dunes, and at lower elevations than those of *A. divaricatus*.

The two color forms of the corolla noted in the description above occur on different shrubs within a population and do not appear to be related to age of the flower. In all other respects, the plants resemble one another.

A collection from a rocky forest on "Plateau Mahafaly" (*Perrier de la Bâthie 9521* at P) contains a small branch that likely pertains to *A. divaricatus*. Like that species, it has round to oblate leaves on petioles up to 5 mm long and corollas with the tube:corolla=0.47. However, it differs from that species by its slightly longer vegetative trichomes (up to 0.5 mm long), larger leaves (up to 15 × 17 mm), smaller corollas (to 17 mm long) with the tube to 8 mm long and not or but barely expanded distally, and smaller anther thecae (1.3–1.5 mm long). Until additional material is available that resembles this collection or that links it to specimens noted herein, *Perrier de la Bâthie 9521* is not included within the circumscription of *A. divaricatus*.

Paratypes.— Madagascar: **Toliara**: NE sector of Tsimanampetsotsa National Park, 24°02.895′S, 43°45.138′E, ca. 22 m, 25 August 2006 (flr, frt), *F. Almeda 9237* (CAS, TAN); Efoetsy, 12 May 1951 (flr), *J. Bosser 187* (P); Lac Tsimanampetsotsa, R.N. 10, February 1962 (flr), *J. Bosser 15,609* (P, TAN); Réserve 10, Lac Tsimanampetsotsa, February 1962 (flr), *M. Keraudren 1403* (P); environs du Lac Tsimanampetsa, environs de l'aven de Mitoho, 23 November 1960 (flr), *J. Leandri & P. Saboureau 4441* (P); Manampetsa, April 1933 (flr, frt), *H. Perrier de la Bâthie 19156* (P); Tsimanampetsotsa Reserve, 24°04′S, 43°45′E, 80 m, 28 December 1987 (flr) *P. Phillipson 2729* (MO); Réserve de Tsimanampetsotsa, SW corner of reserve, 24°11′S, 43°48′E, 50 m, 13 January 1989 (flr), *P. Phillipson & S. Rabesihanaka 3169* (CAS, P, TAN).

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Editor's Note

California Academy of Sciences Research Department Histories

In 2003, the California Academy of Sciences celebrated its 150th anniversary. As part of that event, each of the Academy's research departments was offered an opportunity to prepare an article that addressed the history of the activities of the discipline and department throughout the history of the institution. Given that the Academy was soon to vacate its seismically unsafe buildings in Golden Gate Park and move into temporary quarters in downtown San Francisco, this while the old complex of buildings was demolished and new ones constructed in their place, there was little opportunity for staff to engage in thoughtful consideration of their respective departmental histories. Since the move, and during the time the staff has been in its temporary quarters, several curators have begun to look at their histories, and some have completed manuscripts covering activities in their disciplines from the Academy's founding in 1853 to the present day.

It must be noted that there is no general history of the California Academy of Sciences covering its now more than 150-year lifespan. Several histories, which cover select time frames of the Academy's life, or in one instance its Steinhart Aquarium, have been published (e.g., Aldrich and Leviton [2000], Fritz and Fritz [1982], Hittell [1903], Hittell *in* Leviton and Aldrich (1997), Leviton and Aldrich [1997, 2006], McCosker [1999], and Miller [1942]). Additional histories, some of which relate directly to the departments, have appeared from time to time (e.g., Slevin and Leviton [1956]) or have been included in other, more general studies (e.g., Ertter [2004], Ewan [1953], Slevin [1959], Smith [1987]), and reference is made to one or more of these in the articles that follow.

Although the original intention was to publish all the histories as a single volume, it finally became apparent that this was not about to happen. After much soul-searching, the editor of the *Proceedings* decided to publish the papers as received rather than wait for all manuscripts to be submitted. Thus, at this time, three departmental histories are presented here; additional histories will be published in succeeding issues of the *Proceedings*. The three that appear in this issue are (1) Anthropology, including a separate report on the Rietz Food Technology Collection, (2) Aquatic Biology, and (3) Invertebrate Zoology (although the Department is now known as Invertebrate Zoology & Geology, and includes paleontological and geological collections. Geology and Paleontology will be treated separately).

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A History of Anthropology at the California Academy of Sciences

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Anthropology, as a field of study, has always been part of the California Academy of Sciences, although its level of visibility fluctuated widely over the years. The following pages trace the history of this field at the Academy from its beginnings in the second half of the 1800s, when it was loosely directed by a series of well-intentioned but untrained honorary curators, to its attainment of official status in 1900 with the appointment of Alfred L. Kroeber as the first curator. A series of events, most notably the 1906 earthquake, sent the fledgling department into a 70-year hiatus, although the Academy continued to acquire anthropological materials. The Department was reinstituted in the mid-1970s with the endowment of a curatorial chair and the hiring of a professional staff. Since then, Anthropology has acquired a number of important collections and it has played a vital role at the Academy, particularly in the area of exhibits and other public programs. More recently, original research undertaken by the Irvine Chair of Anthropology has followed more closely the avenues of research by curators in other Academy departments, and the Academy's anthropological collection of primarily ethnographic materials has gained increasing recognition and use by outside researchers and museums. As the Academy prepares to move into a new facility in San Francisco's Golden Gate Park, Anthropology is well poised to continue helping Academy visitors to study and understand themselves.

Anthropology at the California Academy of Sciences has had a checkered yet remarkable history, even though it has existed for only a small fraction of the Academy's history as an official Department of Anthropology. Despite this, anthropologists have been affiliated with the Academy, anthropological collections have been made for the Academy, and anthropological exhibits have been produced in the Academy during most of the institution's 150-years of Academy history. In this paper, we review what is known of the major events and personalities in the history of anthropology as a discipline at the California Academy of Sciences and survey its current collections and activities. As will become readily apparent, the Academy played a major role in the development of the science of anthropology in the United States in the early twentieth century. Although the San Francisco earthquake and fire of 1906 were a disastrous disruption to the pursuit of anthropology at the Academy, interest in the scientific study of humanity at the institution proved unquenchable. The department was eventually reconstituted in 1976, and continues to make many and varied contributions to science and the community.

Early Beginnings

The Academy began to acquire anthropological materials from around the world very soon

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after its founding in 1853. The minutes of the Academy for 25 April 1853 record that one of the first donations made to the institution came from Samuel A. Hastings, who presented "an otter-skin, bows, arrows and quiver, small baskets, a bone drinking-cup, a mountain squirrel skin and a gray-fox skin, obtained by him from the Rogue River Indians" (Leviton and Aldrich 1997:13). Lectures on anthropological topics were also popular in the early days of the Academy, such as that by William Dall in 1868 on the natural history of Alaska and the nature of the "Esquimaux" resident there (Leviton and Aldrich 1997:103). Following the Hastings donation, many materials were given to the Academy in its early days, including the Indian totem pole brought by the Harriman Expedition from Alaska, and dolls dressed in the traditional tribal dress of Yuma Indian women, given to the Academy in 1899 (Leviton and Aldrich 1997:389–390). Others were purchased, such as a collection of bow, arrows and spears of the Macabbe Tribe of the Philippines accessioned in 1899 (Leviton and Aldrich 1997:389–390). Loans of "ethnological specimens" for exhibits outside of the Academy began as early as 1876 (Leviton and Aldrich 1997:194). It is worth noting that the aforementioned Yuma dolls remain in the Academy's collection today, despite having lost their hair and clothes, which were consumed in the 1906 fire.

One of the most significant aspects of the Academy's early anthropological collections is that the majority of materials acquired between 1853 and 1900 were items that represented the material culture of California's rapidly dwindling native populations. According to an inventory of accessions dated 5 December 1896, a great variety and large number of these materials were purchased for Academy collections, from grinding stones and pestles for acorn pounding, to a deer snare, a necklace of pine nuts, and numerous elk horn tools and eating utensils. The collection of baskets in this inventory alone is impressive, comprising baskets for acorn meal, conical carrying baskets, acorn storage baskets, "soup cooking baskets," "soup eating baskets," and women's basket caps. The building of the collection of material culture representing native Californians was to become the major focus of collection-building activity after the official founding of the Academy's Department of Anthropology in 1900.

One of the problems encountered in assembling any wide-ranging history of anthropology is that, prior to 1900, the field was not known by that name. Rather, it was known by the names of some of its constituent fields — ethnology, osteology, and archaeology. It is also important to note that the earliest appointments made by the Academy in the field that was later to be called anthropology were, for the most part, self-taught naturalists who lacked scientific training in any aspect of the field. George Hewston was the Academy's first official appointment in this area, having been named curator of ethnology in 1872 (Leviton and Aldrich 1997:140). Hewston was a man of broad interests: he was also a curator of general zoology and had served as second vice president of the Academy several times. After a short hiatus, Arthur B. Stout was appointed curator of ethnology and osteology in 1876, and again from 1881–1884, and finally, in 1886 (Leviton and Aldrich 1997). Under Stout's stewardship, collections of ethnographic materials grew, and papers on ethnology were read (Leviton and Aldrich 1997). Stout's own interest in ethnology led him to pursue research on the Aleutian Islands and ultimately to write the treatise, "Contributions for the History of the Aleutian Islands" (Leviton and Aldrich 1997:379–380). In 1887, David Wooster began a one-year appointment as curator of ethnology and osteology. In the same year, the famous ethnologist Frank Cushing gave a lecture on his life with the Zuni of New Mexico.

In the years between 1888 and 1896, curatorial appointments in "ethnology," "archaeology, ethnology and lower animals," "osteology," and "archaeology" were variously filled by Adley H. Cummins, Theodore Hittell, Gustav Eisen, Charles Keeler, and J.C. Merriam (Leviton and Aldrich 1997). The polymath Hittell must be singled out for particular attention here, as his keen interest in the ethnology and material culture of native Californians inspired him to read papers at the

Academy such as "Indian Pictographs at Soda Springs, Placer County" in 1890 (Leviton and Aldrich 1997:315.)

Alfred L. Kroeber and the Birth of the Discipline of Anthropology

In 1899, the president of the Academy, David Starr Jordan, began the search for a curator of the newly christened discipline of anthropology. Although it is not clear why Jordan initiated the search at this time, he was no doubt aware of the emergence of anthropology as a comprehensive academic discipline, for instance, at Columbia University under the leadership of Franz Boas. Jordan asked Boas to recommend a suitable candidate for this position, and he first suggested his student and experienced museum collector, Roland Dixon (Jacknis 2002). When Dixon turned down Jordan's invitation, Boas recommended another student, Alfred L. Kroeber, who was then in the late stages of completing his Ph.D. degree at Columbia (Jacknis 2002). Kroeber accepted Jordan's invitation and came to San Francisco in August 1900 (Kroeber 1970). Excerpts from Kroeber's letter of 7 January 1901[1] to the California Academy of Sciences, recorded in the California Academy of Sciences' Officer and Curator Reports for 1900, are relevant here:

> To the California Academy of Sciences:
>
> A department of Anthropology was instituted by your council in the year just past. I was placed in charge September 1.
>
> Obviously, at the outset of a new department, organization was called for, to be succeeded by efforts at development.
>
> In the four months elapsed, the standard scientific system of cataloguing, labeling, and arrangement has been adopted, and applied to the anthropological collection of the Academy. The collection in the Museum was divided into two sections, one devoted to archaeology, the other to ethnology; .... It is believed that the exhibit is now as well displayed as possible with the present limited equipment. New cases are the first requirement if the anthropological portion of the Academy's Museum is to grow....
>
> While organization and preparation required primary attention, there has been considerable growth in the collections. Some specimens have been presented to the Academy, and some obtained by exchange. Field work was carried on both in the North and the South of the State, resulting in a collection of Indian implements and regalia from the Klamath river; a unique collection of baskets; and a miscellaneous collection, largely of pottery, from the Colorado river. Through the cooperation of the American Museum of Natural History, the Academy also secures a series of casts of the [heads and hands] Indians of Middle California....
>
> The results of the year may be summed up in the statement that the department of Anthropology has been put on a satisfactory basis for future work and expansion.
>
> Respectfully,
> A.L. Kroeber,
> Curator of Anthropology

This letter clearly establishes the fact that a Department of Anthropology was formally in place at the Academy in 1900, making it the oldest such department in the western United States. This preceded the founding of the department and museum of anthropology at the University of California at Berkeley in September 1901, the institution recently touted as having the oldest department of anthropology west of the Mississippi (Calpestri 2002; Jacknis 2002).

Kroeber was a paid curator at the California Academy of Sciences from September 1900 throughout most or all 1901. He also received, in 1901, financial support to carry out field research on the lower Klamath River, which he did in the summer of 1901 (Moratto 1976). It appears that

[1] Kroeber's letter is actually dated 7 January 1900. This date is almost certainly in error, as Kroeber had nothing to do with Academy collections before August 1900. At the turn of a new year, it is common for a writer to mistakenly write the previous year when recording a date.

near the end of 1901, Kroeber approached Jordan and the Academy's Board of Directors for further funding for field research. Although initially approved by Jordan, the Board turned down Kroeber's request because it was decided that the Academy would not allocate money to curators for purposes of field research (Moratto 1976). Further, Kroeber was informed that his position would not be renewed for the year 1902 (Moratto 1976), possibly because Jordan felt that Kroeber was too immature to do a proper job. In a letter dated 18 January 1901 from Jordan to Boas, Jordan complained that, "Mr. Kroeber does not have the initiative which will enable him to accomplish here anything of importance outside of purely scientific investigation. He is too young and boyish to produce much impression on men who might be interested in his work, and it seems to be necessary to tell him what to do in order to get anything in particular done, while none of us know what he ought to do" (quoted in Jacknis 2002:530). Kroeber's wife later commented that, "It seems a quaint episode at this distance. There was nothing quaint or amusing about it close up. It is never pleasant to be fired, however pleasantly" (Kroeber 1970:57).

This turn of events did not appear to be a problem for Kroeber himself, as he had by then already secured a position as Instructor at the University of California Museum of Anthropology (Jacknis, 2002). Despite the fact that Kroeber's paid position with the Academy was not renewed after 1901, he continued to serve as honorary curator of anthropology from 1902 through 1905. During this time, he gave "directions in reference to [the collection of] anthropological specimens" to collectors such as Rollo Beck (Leviton and Aldrich 1997:414–415), supervised the accession of collections and duly filed annual reports of the department's activities. In his report for 1905 (dated 20 December 1905), he states, "During this year the Department has experienced an uneventful steady growth.... The total number of specimens in the Department is now above three thousand. As the work of cataloguing the collection was completed a year ago..., the information relating to all of these three thousand specimens, with the exception of a few of the most recent accessions, is now fully recorded."

Kroeber's experiences in working on collections of native Californian materials and conducting field research in northern California in 1900–1901 for the Academy were to be of momentous importance in shaping his career, and the direction of anthropology as a discipline in the United States. It was on the basis of this work that Kroeber developed what was to be a lifelong interest in the material culture and languages of native Californians. He realized that he was living at a unique time in history, when a once highly diverse group of indigenous peoples — the native Califor-nians — was rapidly vanishing. Kroeber's efforts to record the life ways and languages of the groups ultimately resulted, in 1925, in his possibly most influential publication, the monumental *Handbook of the Indians of California*, published by the Smithsonian Institution.

Sometime after Kroeber joined the University of California Museum of Anthropology (Fig. 1), in about 1910, he hired his first assistant (Moratto 1976). This appointment is relevant to the history of the Academy and to the history of anthropology in the United States because the person appointed was Edward W. Gifford. Gifford was hired as a curator of conchology at the Academy at the age of 15, and soon developed an expertise in ornithology as well (Moratto 1976). After leaving the Academy and joining Kroeber in 1910, Gifford went on to become an accomplished anthropologist, distinguishing himself in the study of the natives of the California interior (Moratto 1976). His book, *Miwok Material Culture* (1933), co-authored with Samuel A. Barrett, remains a standard reference for all students of California Native American culture.

By the 1930s, A.L. Kroeber had established himself as the dean of American anthropologists. Kroeber's oeuvre included theoretical and descriptive studies, numbering nearly 500 published works, which covered the breadth of anthropology, from ethnology, linguistics, and folklore to archaeology (Moratto, 1976). His interests even extended to the early evolution of culture and the

nature of culture in nonhuman animals. Kroeber was eventually elected a Fellow of the California Academy of Sciences and, in his letter of acceptance, expressed his warm feelings and esteem for the Academy as the institution that had first attracted him to California and had first ignited his lifelong fascination with its native peoples.

FIGURE 1. Alfred L. Kroeber ca. 1911. Courtesy of the Bancroft Library, University of California, Berkeley. Call number 1978.128 Box 2.

THE EARTHQUAKE OF 1906 AND ANTHROPOLOGY AT THE ACADEMY

The earthquake and fire of April 1906 were catastrophic to the Academy, and resulted in the loss of most of the institution's collections and records. This included all of the Academy's anthropology collections, except for a small assemblage of items that was salvaged, boxed and stored after the fire.

The annals of Academy history record that the only silver lining to the dark cloud of the earthquake disaster was the fact that, at the time of the temblor, the schooner *Academy* was sailing back to San Francisco from its expedition to the Galápagos Islands (with E.W. Gifford, among others, on board), laden with specimens that would catalyze the revitalization of the Academy. As luck or bad luck would have it, the Galápagos were rich in plant and animal life, but were bereft of people or materials of anthropological interest. (The Galápagos Islands lacked an indigenous human population and were first colonized from Ecuador in the seventeenth century. The lack of human influence on the Islands certainly enhanced their biological diversity and richness, but left little for anthropologists.) Although the institution rejoiced at the return of the schooner *Academy* from the Galápagos in November 1906, no anthropological materials were among the thousands of specimens on board. Lacking any material catalyst for the resuscitation of the Department of Anthropology, and with A.L. Kroeber by this time well ensconced at the Museum of Anthropology at the University of California, the Academy in 1906 entered a 70-year long period of quiescence in anthropology, during which no curatorial appointments in the discipline were made. Despite the fact that the Department of Anthropology did not officially exist at the Academy after 1906, collections of ethnographic materials continued to be donated and accessioned. (See section on Significant Collections below.)

The small collection of anthropological artifacts salvaged from the 1906 earthquake had an interesting history. In April 1969, a member of the staff of the Academy's Exhibits Department, Herb Pruett, was exploring the basement of the North American Bird and Mammal Halls in the Academy's premises in Golden Gate Park. There he discovered, in a dimly lit area, a stack of fifteen wooden boxes, most of which were nailed shut. In a few of the open boxes, he discovered a cache of ceramic pots and figurines, wrapped in 1906 newspapers (Richardson 1970). When it was realized that this group of boxes contained the remains of the Academy's pre-1906 anthropology collections, a flurry of activity ensued. A specially devised area near the Exhibits Department was

FIGURE 2. Anthropological collections salvaged from the 1906 earthquake and fire, as they were rediscovered at the Academy in 1969. Photograph courtesy of the Archives of the California Academy of Sciences.

dedicated to the operation of unpacking and cataloguing the materials, and many eager staff and volunteers came forward to assist in the work (Richardson 1970) (Fig. 2). The boxes ultimately yielded several distinct collections: a heterogeneous group of Polynesian artifacts, a group of about 30 artifacts collected by Kroeber made by the Mojave Indians of the American Southwest, and 185 pre- and post-Columbian pots and figurines, plus some tools and jewelry (Richardson 1970). Perhaps the most important of the salvaged materials were those constituting the Elgueta Collection of nearly 1100 Mayan ceramic and stone artifacts. These materials were acquired in 1894 after their display at the Mid-Winter Fair in San Francisco, and made up the bulk of the salvaged items from 1906. To this day it is still not known who was responsible for salvaging the collections from the ruins of the Academy's Market Street premises in June or July 1906. Moratto (1976) speculated that it may have been A.L. Kroeber himself, but this is probably not the case because he later referred to his 1901 collection of Mojave pottery in an appendix entitled, "Memoranda on the Destroyed Academy Collection" (Kroeber and Harner 1955:12). In this appendix, he never indicated that he was aware that any of the Academy's anthropology collections had been salvaged.

In connection with the discovery of the "basement collection" in 1969, the work of one particularly noteworthy volunteer must be singled-out for special mention. Verdi Miller (Fig. 3) volunteered for the Academy for nearly 50 years and — more than any other single individual — kept track of the many anthropological collections in the years before the department was officially reconstituted. Under Verdi's watchful eye and astute direction, the 1906 collection was diligently unpacked, catalogued and conserved, and an important chapter of Academy history partly restored.

ANTHROPOLOGY REDUX

During the early 1960s, staff from the Exhibits Department and volunteers began to catalog the backlog of anthropological collections that had been stored for decades as well as tackle a series of

FIGURE 3. The salvage team at work in the Academy's Exhibits Department on the rediscovered collections of anthropological materials. Verdi Miller pictured second from left. Photograph courtesy of the Archives of the California Academy of Sciences.

new and significant donations of anthropological materials. In the early 1970s the staff of the Exhibits Department was expanded to include specialists in anthropology, namely Christine Russell (now an Academy Trustee), Joan Bacharach, and Nancy Bronstein. By 1975, plans for a major anthropological exhibit were underway. George Lindsay, Director of the Academy from 1963 through 1982, must be credited for seeing the need to revitalize Anthropology as a discipline at the Academy at this time and for formulating the idea for a "Hall of Man." This inspiration was to be made a reality by the generosity of San Francisco philanthropist Phyllis Wattis, a lifelong contributor to the Academy and special patron of its anthropology programs. Lindsay designated Ernest R. Rook, curator of the Exhibits Department, as the coordinator of anthropological exhibits in what was to become the Wattis Hall of Man (Fig. 4). In July 1976, the hall opened, with installations of several of the Academy's most significant anthropological collections, including the Charles and Ruth C. Elkus collection of Southwestern Indian artifacts (Fig. 5) (Lindsay 1976).

FIGURE 4. (A) Groundbreaking for Wattis Hall, 1975. Second from left Mrs. Phyllis Wattis with her son, Paul Jr. on her left; second from right Dr. George Lindsay; (B) The Wattis Hall of Man, ca. 1978. Photographs courtesy of the Archives of the California Academy of Sciences.

George Lindsay realized that the health of anthropology as a discipline at the Academy could only be maintained by a committed scientific staff. Therefore, on 1 July 1975 the Department of Anthropology was officially reinstated, with Joan Bacharach (who had been serving as Curatorial Assistant for anthropological collections in the Exhibits Department) as Acting Chairman. In the

FIGURE 5. Selected items from the Elkus Collection of Native American art. Photograph by Dong Lin, California Academy of Sciences.

same year, Lindsay was instrumental in securing a grant from the James Irvine Foundation of $250,000 for the establishment of an endowed chair of anthropology. This amount was matched by the Academy, thus making possible the Irvine Curatorial Chair of Anthropology (*California Academy of Sciences Annual Report for 1975–1976*, p. 13). At that time, the principle activity of the Department was described as "the proper conservation of its collections, and continuing service to the Exhibits Department in their shared responsibility for anthropological exhibit development" (*California Academy of Sciences Annual Report for 1975–1976*, p. 14).

The Department of Anthropology was officially reorganized under Dorothy K. Washburn as Chairman and Assistant Curator in 1978. Washburn was, thus, the first official holder of the Irvine Chair of Anthropology. She was instrumental in developing further exhibits for the Wattis Hall of Man, and was primarily responsible for developing and producing the catalog for one of the Academy's most successful anthropological exhibits, "Hopi Kachina: Spirit of Life" (*California Academy of Sciences Annual Report for 1979–1980*, p. 11). Washburn's primary research was design structure or symmetry analysis of cultures, including Southwest Indian ceramics. This interest led her to publish many scholarly papers and books, including the edited volume, *Structure and Cognition in Art*, released by Cambridge University Press in 1983 (*California Academy of Sciences Annual Report for 1981–1982*, p. 11). Her 1988 publication, in collaboration with D.W. Crowe, *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis* (University of Washington Press), features illustrations of many items from the Academy's collection. Washburn was also the driving force behind the book, *The Elkus Collection: Southwestern Indian Art*, published by the California Academy of Sciences in 1984, although it was completed by Robert Sayers. Among all the holders of the Irvine Chair of Anthropology since 1978, Washburn is the individual whose research was most closely tied to the collections of the Anthropology Department.

In 1982, Robert Sayers joined the Department of Anthropology as a Visiting Assistant Curator and Acting Chairman while Washburn was on research leave. Sayers, an expert on East Asian material culture, in particular Korean pottery, then took on the administrative duties of the department and the teaching of the docent course for the Wattis Hall of Man (*California Academy of Sciences Annual Report for 1982–1983*, p. 14). The Smithsonian Institution published his monograph, *The Korean Onggi Potter* in 1985. Diane Lee Carroll joined the Department as a Research Archaeolo-

gist in 1982 and completed her analysis of the department's valuable collection of Coptic textiles (*California Academy of Sciences Annual Report for 1982–1983*, p. 14). This research led to her publication of the widely cited catalog, *Looms and Textiles of the Copts*, in 1988.

It was under Sayers' direction that famed primatologist Jane Goodall joined the staff of the Anthropology Department as Honorary Curator of Anthropology, first in 1983–1984 (*California Academy of Sciences Annual Report for 1983–1984*, p. 33), then as Curator of Primatology from 1985 through 1987 (*California Academy of Sciences Annual Report for 1985–1986*, p. 27; *Ibid.* for 1986–1987, p. 19; *Ibid.* for 1987–1988, p. 22).

Washburn held the Irvine Chair of Anthropology until her retirement in 1983. Sayers remained Acting Chairman until July 1984, when Norman Hammond was appointed as the department's second Irvine Chair of Anthropology. Hammond, a Mesoamerican archaeologist and Maya scholar, remained in the department for only one year, during which he mapped large portions of an ancient Maya city in Belize and excavated major structures there. The Irvine Chair was vacant for a short time after Hammond's departure, until the appointment of Linda Cordell as the third Irvine Chair of Anthropology in 1986. Cordell, an archaeologist with a specialty in prehistoric Pueblo cultures of the American Southwest, remained in the position until 1993. During her tenure, she continued to offer training in anthropology for docents guiding the Wattis Hall of Man, and energetically pursued archaeological fieldwork in the Rio Grande Valley of New Mexico. Her research was (and continues to be) concerned with reconstructing the economic, social and political organizations of the late prehistoric Pueblo period from about 1275 to just before the Spanish entered the Southwest in 1540. Cordell left the department in June 1993, at the same time that the decision was taken to dismantle the Wattis Hall of Man in order to create a large venue for temporary or traveling exhibits.

In 1994, the vacant Irvine Chair was advertised with the specific goal of attracting to the position a physical anthropologist, who would be well-suited to communicate and collaborate with other curators in various fields of systematic biology who comprised the growing scientific staff of the California Academy of Sciences. Nina Jablonski was appointed the fourth Irvine Chair of Anthropology in that year, and joined the Academy's staff in December 1994. During her tenure, Jablonski maintained a wide-ranging research program in primatology and human evolution and worked diligently to maintain the presence of anthropology on the public floor of the Academy following the closing of the Wattis Hall of Man.

Anthropological Collections at the Academy

Through thick and thin, including the comings and goings of curators in the last twenty years, anthropology has maintained its integrity and its public visibility because of its collections. Despite being nearly completely destroyed by the 1906 earthquake and fire, anthropological collections literally rose from the ashes and slowly grew at the Academy during the twentieth century. The absence of a formally constituted department for nearly three-fourths of the century meant, however, that — for the most part — Academy staff were not actively engaged in making collections of anthropological materials, as they were, for instance, in botany and herpetology. Rather, the collections grew fairly randomly as the result of donations. When these post-1906 collections were reviewed and catalogued in the 1960s and 1970s, the eclectic nature of the collection and the parlous condition of the documentation for many objects became apparent. Since the late 1980s, the staff of the Department of Anthropology has been engaged in a process of improving the documentation on selected collections, and of paring down others by de-accessioning materials clearly unrelated to anthropology (e.g., a bedspread purported to have belonged to Napoleon's wife, Josephine; and a collection of old electric light bulbs) to other museums and institutions. There has also been an increased focus on computerization of information on the Academy's anthropology collections.

This has resulted in the entire collection database (complete with images), along with many "online only" exhibits, now being available on the internet (*www.calacademy.org/research/anthropology*).

At present, the collections of the Department of Anthropology comprise approximately 17,000 items. The main focus of the collections is on ethnographic materials from the western United States, mostly the American Southwest, California, and Alaska. The secondary focus is the material culture of the islands of the Pacific and of the Pacific Rim. It is appropriate here to summarize the major collections that support these foci.

Allen Lamp Collection: Donated in 1952 by Maude Rex Allen, this international collection of lamps and other lighting devices numbers nearly 300 items, spanning several millennia and representing nearly every continent. It was exhibited at the Academy in 1952–1953.

Liebes Native Alaskan Collection: Donated in 1960 by Grace Liebes, this collection of nearly 1000 Native Alaskan objects was assembled by her husband, Arnold Liebes, whose family had long operated a fleet of merchant ships between San Francisco and Alaska, as well as a number of frontier trading posts in the Alaskan Territory. In addition to two full-sized kayaks, two baleen baskets, items of native clothing and household items, and souvenir ivory items, the collection is especially rich in bone and stone tools (Fig. 6).

Elkus Native American Collection: Donated in 1972 by the children of Ruth and Charles de Young Elkus, in accordance with their parents' wishes, the Elkus Collection is the largest and most important anthropological collection ever given to the Academy (Fig. 5). It is without question the core of the department's Native American holdings, and comprises nearly 1700 objects, including textiles, jewelry, baskets, pottery, works of art on paper, katsina carvings, and beadwork. The cultural focus is the U.S. Southwest, but California, Alaska, the Northwest Coast, and Plains regions are also represented. The collection is especially important because it was assembled during the formative years of the modern Native American art market, and includes early works by artists who eventually earned international acclaim and have influenced succeeding generations of Native American artists. This collection was published in 1984 in *The Elkus Collection: Southwestern Indian Art*, edited by Dorothy Washburn and Robert Sayers; it has been used in numerous exhibits at the Academy and at many other venues. A large portion of the collection was shown in the exhibit, "The Elkus Collection: Changing Traditions in Native American Art," from 1999 until 2003 (Fig. 7).

FIGURE 6. Selected items from the Liebes Collection of Native Alaskan art. Photograph by Dong Lin, California Academy of Sciences.

FIGURE 7. A view of the exhibit, "Elkus Collection: Changing Traditions in Native American Art", 1999. Photograph by Dong Lin, California Academy of Sciences.

Rietz Food Technology Collection: Placed on loan to the Academy in 1974 and officially donated in 1989, this collection of food-related items was assembled by Carl Austin Rietz, a lifelong leader in the food industry and inventor of many twentieth Century food devices, not least of which is the industrial food processor. Some 1300 objects illustrate methods of producing, processing, storing, preparing, and serving food among cultures from around the world (Fig. 8). The collection is particularly strong in European and American cutlery and other utensils, Japanese tea kettles, and Persian and other Middle Eastern ceramic wares. (See also Evans 2007 [this volume].)

Rietz Coptic and pre-Columbian Textile Collection: Also among Carl Austin Rietz's interests were early textiles. Accordingly, he collected and eventually donated (along with the food technology collection) approximately 75 fragmentary Coptic textiles from the first millennium Egypt. As mentioned above, a complete study of this collection was published in 1988 by Diane Lee Carroll. Rietz also collected and donated approximately 30 complete or nearly complete pre-Columbian Inca clothing items from Peru. The collection was exhibited in the Academy's Patricia Price Peterson Gallery in 1978.

Ostheimer Hawaiian Collection: Donated in 1976 by Alfred and Jacquenette Ostheimer, this collection of nearly 500 Hawaiian objects is reportedly the largest collection of early Hawaiiana on the U.S. mainland (Fig. 9). It includes stone woodworking and food-processing tools, wooden bowls, fishing equipment, feather leis, a fragmentary warrior's helmet, kapa (bark cloth) fragments, and many other utilitarian items. The Ostheimer Collection was exhibited in Lovell White Hall in 1977 (*California Academy of Sciences Annual Report for 1976–1977*, p. 6).

Torry Gabra Collection: In 1977, the Academy sponsored a field collecting expedition, headed by William I. Torry, among the Gabra people of Kenya, in order to develop an exhibit for the newly opened Wattis Hall of Man. Torry collected some 500 household and other utilitarian objects that reflected daily life of the Gabra people. An almost identical collection was also made for the National Museums of Kenya.

Owings Katsina Collection: Nathaniel Owings donated his extensive collection of more than 100 Hopi and Zuni katsina carvings to the Academy in 1978 (Fig. 10). The collection was the impe-

FIGURE 8. Selected items from the Rietz Food Technology Collection. Photograph by Dong Lin, California Academy of Sciences.

FIGURE 9. Selected items from the Ostheimer Collection of Hawai'iana. Photograph by Dong Lin, California Academy of Sciences.

tus for a major traveling exhibit, "Hopi Kachina: Spirit of Life", mentioned above, which was produced by the Academy in 1980 and later shown in Chicago, Pittsburgh, New York, and Washington, DC.

Beck South Pacific Collection: In the late 1920s, Ida and Rollo Beck were members of the American Museum of Natural History's Whitney Expedition to the South Seas, whose purpose was the collection of natural history specimens for the AMNH collections. Beck was a trained ornithologist with a long association with the California Academy of Sciences, and he and his wife were also avocational anthropologists. In their spare time during the expedition, they assembled a personal collection of ethnographic materials and photographed the native people on the islands they visited (Fig. 11). Part of their collection was later sold to the Burke Museum at the University of Washington, but the Becks retained nearly 400 objects from at least 14 distinct South Pacific island

FIGURE 9. Selected items from the Owings Katsina Collection. Photograph by Dong Lin, California Academy of Sciences.

FIGURE 11. Selected items from the Beck Collection of ethnographic artifacts from the Pacific Islands. Photograph by Dong Lin, California Academy of Sciences.

groups. Many of the objects are well documented as to time and place of collection. The collection, along with thousands of photos and original field journals, was donated to the Academy in 1984 by Beck family heirs.

Elgueta Mayan Collection: The Mid-Winter Fair held in San Francisco in 1894 included a large display of pre-Columbian Mayan ceramics, owned by Manuel Garcia Elgueta. The collection had previously been shown at the Chicago's Columbian Exposition in 1892. Following the San Francisco fair, the Academy acquired the collection, possibly through purchase. The collection holds some of the only documented pieces from Pichikil and Chalchitan, two pre-Columbian sites in Highland Guatemala that have been heavily looted over the years. Although the Elgueta Collection was very heavily damaged during the 1906 earthquake, more than 1100 items survived, including ceramics and jade earspools, beads, and pendants.

Kadota Mingei Folk Toys: Hiroyuki Kadota grew up in Kyoto and shortly after his marriage in the late 1950s, began collecting examples of traditional handmade folk toys, because he recognized that many toy makers were abandoning age-old traditions in favor of mass produced materials or labor-saving techniques. Visiting shrines and festivals in every prefecture, Kadota collected more than 600 whimsical objects that function on many levels in Japanese society. He donated the entire collection to the Academy, beginning in 1992. The collection was displayed in Wattis Gallery (adjacent to Wattis Hall) from 1996–2000.

Stephens Horological Collection: Donated in 1946 by Dr. William Barclay Stephens, founder of the Bay Area chapter of the National Association of Watch and Clock Collectors (NAWCC), the collection includes nearly 500 watches and clocks of all kinds. The collection is especially strong in pocket watches by early American watchmakers, and was on public display at the Academy from the 1940s until the 1970s. In 1997, an agreement was reached between the Academy and the NAWCC Museum in Columbia, Pennsylvania, that permitted the long-term loan of the collection to the latter museum. Since 1998, the Stephens Collection has been housed in its entirety at that facility, with some of it now on display.

Pre-1906 Collections: As discussed above, most of the Academy's anthropological collections were destroyed as a result of the 1906 earthquake and fire. However, several hundred items, including textiles, baskets, stone tools, pottery, and other objects, were ultimately salvaged (Fig. 12). Some of these were heavily damaged, while others were inexplicably spared. Although all catalog records were lost, the histories of some of these objects have been pieced together as clues occasionally come to light. In addition to the previously described Elgueta Mayan Collection, notable pre-1906 objects that survived include the following:

Some 30 pieces of Mojave Indian pottery, the only extant Academy collection known to have been collected by A.L. Kroeber during his short tenure as Curator of Anthropology;

A small collection of Maori stone tools collected by C.D. Voy, who apparently assembled collections for a number of early museums, especially the University Museum at the University of Pennsylvania;

A very, very large kava bowl, a tortoise shell sacrificial hook, and a carved gaming implement, all early pieces from Marquesas and all illustrated by line drawings in a rare 1896 publication highlighting South

FIGURE 12. Selected "survivors" of the pre-1906 collection of anthropological materials rediscovered at the Academy in 1969. Photograph by Dong Lin, California Academy of Sciences.

Pacific collections in museums around the world;

Several very early pieces of tapa cloth;

Several hundred northern California Indian "charmstones";

Numerous California Indian and Alaskan baskets;

A rare full-sized human funerary effigy from Vanuatu (which was displayed along with other objects and photographs by David Becker in the temporary exhibit, "At Home in Vanuatu: Tradition in the Western Pacific," in 2000; and

A suit of Samurai armor with a rare *kaware kabuto* or "spectacular helmet."

Anthropology and the Community: the Traditional Arts Program

The rebirth of anthropology as an academic discipline and department at the Academy in the mid-1970s included a new element that was probably unique among anthropology departments at that time. The Living Arts Program, begun in 1976 and directed by ethnomusicologist Sandra McCosker, brought ethnic artists to the museum to present their traditions for the public. The program was supported from 1976–1980 by a grant from the National Endowment of the Arts. The popularity of this program led to an even more enduring and successful one, the Traditional Arts Program, which came into being in 1983.

The Traditional Arts Program (TAP) was initiated by the efforts of Robert Sayers, then Acting Chair of the Department of Anthropology. Sayers envisioned a weekly series of ethnic art presentations for museum visitors and successfully applied to the National Endowment for the Arts for start-up funding. June Anderson was hired in July 1983 to organize the fledgling program, which debuted on September 10, 1983, with a performance of African dance.

The goal of the TAP was to expand the Academy's outreach into local ethnic communities by offering artists the chance to participate in a variety of cultural heritage presentations — music and dance performances, craft and food demonstrations, storytelling, puppet shows, and other expressions of daily and ceremonial life.

By the end of its first year, the TAP was firmly established and had built up a regular audience of enthusiastic aficionados. Museum-goers welcomed the opportunity to learn about the artistic heritage of the many immigrant and Native American groups that make up the demographic profile of the San Francisco Bay Area, and participating artists appreciated having a public venue for interpreting their traditions. The ongoing Saturday afternoon programs proved to be both educational and entertaining. At times, the art programs tied in with themes of museum exhibits, or were scheduled to coincide with an annual celebration, such as Mexican Cinco de Mayo or Chinese New Year.

Initially, the format of the TAP was merely a series of ethnic art presentations for museum visitors (Fig. 13). It soon became obvious that members of the audience were eager to expand their understanding of each art form in its broader cultural context. Audience handouts were introduced to explain the social significance and function of the art, as well as its historical and geographical origin, and included biographies of the artists and general information on the ethnic group featured each week. In addition to the research required for each presentation, Anderson and her staff made a commitment to conduct ongoing fieldwork within local ethnic neighborhoods, and to augment our knowledge of cultural traditions by documenting every Saturday presentation, through tape recordings, transcripts, and slide photography. This was the beginning of the TAP archives, the foundation on which the ethnographic files of the Department of Anthropology have continued to grow over the years. Today the archives provide an invaluable resource to individuals or institutions seeking information on California's ethnic diversity.

In 1984, when the one-year trial period was over, the program's achievements were assessed and its future prospects evaluated. It was apparent that the program had contributed to the

FIGURE 13. Scenes from performances and demonstrations of the Traditional Arts Program. a) The Von Konsky Dancers perform a German maypole dance (July 1988); b) Luis Gervasi makes South American clay flutes (June 2001); c) The Sun Eagle Drum Group perform Plains Indian music and dance, including the hoop dance (March 1985); and d) Onye Onyemaechi performs Nigerian drumming (February 2002).

Academy's educational mission — "to explore and explain the natural world," including human cultures – and it was resolved to seek private funding to ensure the continuation of the TAP, since internal funds were not available and the NEA would not extend its grant for a second year. Local philanthropist Phyllis Wattis, a long-time patron of the Academy, offered to finance the TAP on a year-by-year basis, thus saving the program from extinction. From 1984 to 1988 Mrs. Wattis provided annual funding to the TAP and then, in a truly magnanimous gesture, decided to permanently fund the TAP with a one-million-dollar endowment, awarded in September 1988. The program was thus free to continue and expand in new directions, including the inauguration of a student internship program; this was the beginning of a very worthwhile and successful partnership with universities in California and across the country. The internship program has also attracted partici-

pants from around the globe, including students from Russia, England, Singapore, and Denmark. Over the years, the projects of student interns have contributed much to our knowledge of ethnic arts, while the interns themselves have gained practical experience in applied anthropology and museum studies, and obtained course credit towards their degrees.

In 1991, an Artists-in-Residence program was added to the TAP, thanks to a grant from the Institute of Museum Services. This made possible three-month series of residencies whereby guest artists demonstrated their crafts daily in the museum. Some of the first participants were the Turkish carpet-weavers, who have since returned to the museum nearly every year since. The residencies remain a popular attraction with museum visitors.

By the mid-1990s, the TAP had expanded rapidly and had embraced a host of new projects. Fieldwork and research intensified and extended beyond California to include studies in Ecuador, Turkey, Australia, and Guatemala. The workload demanded a permanent addition to the staff, and a new position was created in 1995. June Anderson became the new Traditional Arts Supervisor, to oversee the program and to produce publications on ethnic art, while a TAP Coordinator was appointed to be responsible for the weekly performance series. Since that time, Anderson has produced a series of engaging publications, which have brought particular areas of folk art to popular attention. These began with *Mayko's Story: A Hmong Textile Artist in California* (1996) and continued with *Honoring the Ancestors: The Woodcarvings of Claude Lockhart Clark* (1997) and *Return to Tradition: The Revitalization of Turkish Village Carpets* (1998).

The TAP celebrated its twentieth anniversary in 2003, the year of the Academy's sesquicentennial. Through its history, one continuous thread has bound the program together conceptually: A deep concern with people and their interactions. This has embraced the mission of people passing on their traditions to the next generation, people from diverse ethnic backgrounds co-existing in our multicultural society, and people visiting the museum and meeting the artists. Students, volunteers, donors, and staff, have worked together and contributed to the growth of the TAP, and this is the enduring strength of the program. Insulated by its endowment from the vicissitudes of budget fluctuations, the TAP is one of the most successful and the single longest-lived public program in the Academy's history.

Anthropology at the Academy in the Twenty-first Century

The Department of Anthropology at the California Academy of Sciences is financially supported largely by endowments — that of the James Irvine Foundation supporting the curatorial chair and that of the former Wattis Foundation supporting the Traditional Arts Program. The security that this has imparted has been critical, especially considering the Department's small size (six salaried staff in 2002). The growth of these endowments and of other foundation income has also permitted the scope of the Department's activities to increase in recent years.

Symposia supported by the Rietz Food Technology Foundation and the Wattis Foundation have occurred on a regular basis at the Academy since the early 1980s. Past Rietz Symposia have included "Chilies to Chocolate" (1988), "Celebrating Spring" (1992), "Foods of the Future" (1994), "Bread, A Language of Life" (1996), and "Food: Health and Healing" (1998). These symposia have become popular with Bay Area audiences not only because of their interesting topics, but because the conclusion of each symposium featured an elaborate tasting party, featuring dishes related to the symposium theme. Although only one Rietz Symposium resulted in a publication, *Chilies to Chocolate: Food the Americas Gave the World* (Foster and Cordell 1992), it has been one of the best-selling anthropological publications ever produced by Academy staff.

The Wattis Symposia in Anthropology commenced in the mid-1990s and were established with the explicit goal of bringing "state of the art" anthropology to the general public. These symposia

have not only been popular successes, but have heightened the profile of academic publications of the Academy because each symposium has been published as an edited, peer-reviewed Memoir of the California Academy of Sciences, which together constitute the Wattis Series in Anthropology. These comprise *Contemporary Issues in Human Evolution* (Meikle et al. 1996), *Beyond Art: Pleistocene Image and Symbol* (Conkey et al. 1997), *The Origin and Diversification of Language* (Jablonski and Aiello, 1998), and *The First Americans: The Pleistocene Colonization of the New World* (Jablonski 2002).

The collections of the Department of Anthropology at the Academy may not be the institution's largest, nor its staff the most numerous, but the Department contributes greatly to the Academy's mission as a result of its vitality, high levels of productivity, and great diversity. This is brought about not only by the research of its curators, but also by bringing anthropology into peoples' lives through exhibits, the Traditional Arts Program, and its academic symposia. This is certainly a legacy befitting the oldest anthropology department in the American West.

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This chapter is dedicated to the late George Lindsay and late Phyllis Wattis, the staunchest supporters and friends of anthropology at the California Academy of Sciences during the twentieth century.

Postscript

The preceding article was originally written in 2002 in anticipation of the Academy's 150th anniversary in 2003, but for various reasons it was not published at that time. In the intervening years, much has transpired. In 2004, the entire Academy temporarily relocated to downtown San Francisco while an entirely new facility is being built on its former site in Golden Gate Park. Staff will begin moving into that facility in early 2008, and it will open to the public later in the year. During the transition, no Academy department was spared from downsizing. Anthropology's *Traditional Arts Program* was suspended in 2006, but it will resume when the new facility opens. Nina Jablonski left the Academy in August 2006, and a new Irvine Chair of Anthropology is expected to be hired in the near future. Anticipation of the new Academy has spurred the promised donations of several important Native American collections. The Department of Anthropology is well poised for growth in the years ahead and expects to build upon the research, collections, and programs that have been described in this article.

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The Rietz Collection of Food Technology Department of Anthropology, California Academy of Sciences

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The Rietz Collection of Food Technology is housed in the Department of Anthropology at the California Academy of Sciences and was amassed by Carl Austin Rietz during the mid 20th century to document the cultural development of technologies associated with preparing and eating food among numerous cultures and time periods. Rietz, a pioneer of industrial food processing, collected the objects during his world travels that spanned several decades and intended the Collection as a tool for cross cultural comparison and education. The Collection contains 1328 objects originating in ancient Palestine, Cyprus and Greece, Medieval Persia, Renaissance Europe, Colonial North America, 19th century Japan and China, as well as early 20th century Africa and Oceania used for the serving, preparing, and storing of foods. Composed of diverse materials such as stone, clay, bone, ivory, leather, wood, plant fibers, glass, and various metals and metal alloys, the objects in the collection illustrate the variety of tools developed and used for eating and cooking worldwide. Areas of representation include the development of cutlery and chopsticks, serving and tableware, household and professional cookware, domestic hearth tools, and storage containers. The Collection lacks detailed provenance for most objects, but a basic understanding of Rietz's life and collecting practices helps to uncover information about the origin and identity of individual objects and groupings thereof. The materials in the Collection provide an important resource for scholars investigating material practices related broadly to food within the fields of anthropology, history, or culinary arts.

The Rietz Collection of Food Technology (henceforth referred to as the Collection) is one of the few and perhaps, only, cross-cultural collections of culinary objects assembled to document historic technologies of cooking and eating. It consists of 1328 objects and tools used for the collection, preparation, serving, and storage of food. The objects represent the technologies of eating and cooking of numerous cultures, time periods, and environments. Examples range from 10th to 6th century BCE Mediterranean household terra cotta cookware to 19th century English and French professional culinary pots and pans and 20th century Africa and Oceania. The highlights of the Collection include almost every example of the development of the knife and fork in Europe from the Renaissance to the early 19th century, colorfully glazed serving ware from Medieval Persia, 18th and 19th century French and English measuring cups used for trade, as well 18th century domestic, hearth tools from North America and Europe.

The California Academy of Sciences received the Collection from the family of the late Carl Austin Rietz in 1974. An early pioneer and inventor of industrial food processing, Rietz had traveled widely to install and promote his machinery used for large-scale food processing. In the course

of his travels, he collected historic objects related to the various aspects of food processing. Rietz created his Collection to illustrate cultural comparisons. He saw the act of preparing and sharing food as a universal practice among cultures and, thus, as an avenue for exploring cultural diversity. His goal, to share knowledge of other cultures with those from his own culture in hopes of illustrating the commonality of all cultures,, was thus educational, as he attempted, through the lens of cooking and eating, to promote peace and cultural understanding through shared knowledge of cultural practices.

The Collection

Currently housed in the Department of Anthropology at the California Academy of Sciences, the Collection consists of objects related to food technologies and an image collection of culinary themed illustrations, engravings and prints, as well as a collection of 7500 color film transparencies depicting industrial food processes and technologies of the 1950s and 1960s.

The objects in the Collection are, by definition, utilitarian and represent over three millennia of cooking and eating. With many cultures and time periods represented, classification of the objects could be a monumental project. However, most can be classified in a manner consistent with an anthropology or natural sciences collection, according to the region and cultural area from which they originated. The groupings employed by the collections staff of the Department of Anthropology at the California Academy of Sciences are the following: East Asia, Southeast Asia, Southwest Asia, South-Central Asia, North Africa, Sub-Saharan Africa, North America, South America, Mexico and Central America, Australia, Oceania, and Europe.

Access to the Collection is available through the Internet on the California Academy of Sciences website: *<http://www.calacademy.org/research/anthropology/collection/collintro.htm>*. The Collection database provides current physical descriptions, locations, and digital images of most objects in the Anthropology Collection.

Over 800 objects from the Collection have been exhibited either at the California Academy of Sciences or by other institutions. Institutions in the San Francisco Area that have borrowed objects for display include the Fine Arts Museums of San Francisco, the California College of Arts, San Francisco Airport Commission Bureau of Exhibitions, Natural History Museums, and Cultural Exchange, The San Francisco Yacht Club, San Francisco State University, and the University of California San Francisco. Other institutions in California and the United States that have displayed objects from the Collection include the American Museum of Natural History in New York, the City of Palo Alto, California, the Jesse Peters Memorial Museum at Santa Rosa Junior College, and the de Saisset Art Gallery and Museum at the University of Santa Clara.

In addition to exhibits of objects, the Collection has been an integral part of the Rietz Food Symposium presented by The California Academy of Sciences and The Rietz Food Technology Foundation. Rietz Symposia were held from the mid-1980's through the 1990s at the California Academy of Sciences with a general theme related to historical and contemporary food traditions:

1983	Bay Area Culinary Traditions.
1986	Chinese Culinary Traditions in the Bay area.
1988	Chiles to Chocolate: Foods The Americas Gave the World.
1990	Bounty By The Bay: A Region's Culinary Heritage.
1992	Celebrating Spring: Foods and Festivals of the Season of Renewal.
1994	Foods for The Future: Anticipating Tomorrow's Table.
1996	Bread: Staff of Life.
1998	Food: Health and Healing.

Documentation of the Collection

Rietz left little information regarding his thoughts, intentions, or goals for the food-related objects he had collected. As his collections grew, Rietz did not articulate a general plan or mission regarding the scope of materials he hoped to collect. It is not clear if Rietz kept a collection journal or collection notes, as none have been found among his papers. However, in a letter dated March 6, 1956, found with invoices from a trip to Europe in 1955–56, Rietz mentions the following:

> Within the next month or so I hope to get down to the project of making a set of sketches and some notes of my interests in a number of different things; the arts and artifacts of antiquity, particularly the knives and spoons and bowls of metal, bronze and iron, from the earliest historical period up to the Medieval and early Renaissance. (Rietz Archive, Box 3)

His intent was obviously to document some of his ideas about what and why he was collecting, but unfortunately he seems not to have had the opportunity.

A corresponding difficulty with the Collection is the overall lack of provenance for the individual objects. Rietz left little information about where and how he gathered the objects he found all over the world as well as basic information about each object. Without verifiable provenance, information on its date of manufacture, use, or material composition, the use of the collection for scholarship and study is problematic.

The only surviving paper work from Rietz consists of the collection files that accompanied the Collection when it was first received at the California Academy of Sciences. The Rietz archive located in the library of the California Academy of Sciences provides a modest paper trail of his collection travels and practices. Receipts and invoices from antique dealers, galleries, curio shops, and museums provide evidence of his purchases. Customs papers, tax duty receipts, and income tax statements give descriptions of objects and their origins as well as their estimated value. Equally valuable in the archive are itineraries of his travels and some correspondence related to purchases, vaguely outlining how he built his various collections over thirty years.

Research in the papers of the Rietz Archive and corresponding collection inventories that accompanied the Collection have provided information about his collection practices and his intentions for the use of the Collection. Interviews with his daughter, Betsy Rietz Dingwell, have also proved to be helpful in uncovering the intentions and collection practices of Rietz and to some degree, his motivations. These documents and interviews attest to not only the variety of his collecting tastes, but also to his desire to share his finds. The Archive also describes, through some limited correspondence and money transfers, his support of universities and museums through donations of his collections or financial support of foundations dedicated to education.

A Short Biography of Carl Austin Rietz

Carl Austin Rietz was born on August 3, 1894 in New York City. He spent his childhood and adolescence in the San Francisco area, later attending Columbia University, Harvard and the Massachusetts Institute of Technology, as well as the University of Maryland and Johns Hopkins University, where he studied medicine. It is unclear as to which degrees or fields of study were completed by Rietz during his years of academic training, but eventually he earned an engineering degree from the University of California at Berkeley. Rietz served in World War I as an ambulance driver and later worked as a private secretary for the famous mining engineer John H. Hammond, as cameraman for D.W. Griffith in Los Angeles, and as secretary to Thomas A. Edison. A Rietz family anecdote tells of how the young Rietz, by scoring one of the highest marks on the famous inventor's first comprehensive IQ tests, secured his position with Edison.

Medical school in Maryland piqued Rietz's interest in diet, nutrition and food processing. In 1931, as a result of his training in engineering, medicine and draftsmanship, he designed the first Rietz Disintegrator — a device for pulverizing the desirable parts of raw foods, ejecting inedible parts such as bone, seeds and stems. His "vertical" machine was easy to sterilize and was such an improvement over existing disintegrators that it became the standard for the food, chemical and paper processing industries. His innovations, although considered radical in the 1930s and 1940s, would soon become foundational to modern, industrial processing not only in the United States but also world-wide.

International interest in the Rietz Disintegrator continued to grow after World War II, prompting extended travel throughout the world for the remainder of his life. Rietz was called upon by the Economic Co-operation Administration, a post war economic program of the United States Government, to survey the needs of European nations regarding food processing machinery and infrastructure. This effort was instrumental in the integration of modern mechanization practices into European agricultural processing. Rietz also worked with the Ralph M. Parsons Group as a consultant in establishing mechanization of modern fishing and fishing industries in the Red Sea area of the Middle East. During his travels of this period, Rietz's storehouse of information about the different cultural attitudes and practices around food and eating was gained first hand through the meals he shared with local peoples. He disdained eating in places with normal tourist fare and sought out the authentic cuisine particular to a specific locale and culture.

Rietz did not restrict his exploration of world cuisines to contemporary meals of the countries he visited. His understanding of food processing technologies coupled with his interest in international cuisine and history led him to explore the history of how people of different cultures have tackled the basic requirement of feeding themselves. He had a personal philosophy, often repeated by those who knew him, that the formula for world peace was the honest understanding of other cultures. He viewed food and cuisine as an obvious tool for such cultural understanding. As he traveled, he began to search out the historic artifacts that told the story of cooking and eating in each place he visited. His interest was broad and he chose objects primarily as examples of technology rather than for their craftsmanship. His primary interest was in how an object was used rather than how it was made.

Rietz's responsibilities in the reconstruction of post -WW II Palestine in the late 1940s led to his acquiring a varied collection of ancient Palestinian artifacts related to all aspects of food technology. This first collection of food utensils was the beginning of his focus on the collecting of historical food technology and remains a significant part of the present Collection. It consists of metal utensils and clay vessels and dates from a period spanning the second century B.C.E. to the second century C.E. The foods and dining practices described in biblical texts became one of his research interests and he would later use this collection of artifacts for demonstrations and lectures on the subject of New Testament era cuisine and ritual. The wedding of his daughter Sandra garnered media attention in 1955 due to his unconventional use of ancient artifacts in the ceremony. Rietz incorporated elements of biblical marriage rites complete with period wine cups and oil lamps. The wedding cake was the size and shape of a beehive, served with other foods Rietz had researched for their connection to ancient ways of celebrating the marriage union.

Documentation for the Collection is best for 1950-era objects, when it appears that Rietz's business interests, travel and collecting began to be fully integrated. The bulk of invoices, receipts and customs papers in the Rietz archive date from this period. It is at this time that Rietz acquired the majority of his collection of artifacts related to food technology and developed relationships with specialists in several disciplines at Mills College in Oakland, California. In 1951, President White of Mills College appointed Rietz to a lectureship in International Cuisine and Food

Technology. He traveled extensively during the following year to Africa and the Middle East, as well as to Austria, Sweden, England, and Scotland. In 1953, the first home for his extensive collection of food related artifacts was established as The Rietz Food Technology Foundation at Mills College with what was described as an "object collection in illustration of the progress of science." The next few years saw Rietz engage in extensive global travel and collecting in ceramics, textiles, food artifacts, folk art, and books. In 1955, Rietz appeared on KRON television in San Francisco in a program featuring the Food Technology Collection. At about the same time, he hosted a series of thirteen, one-hour radio broadcasts on San Francisco's KQED titled, "Food, Fire, and Folklore."

In the early 1960s, although occupied with the expansion and relocation of Rietz Manufacturing from San Francisco to Santa Rosa, California and extensive travel, Rietz managed to author a treatise outlining a scientific approach to selecting, preparing, and cooking food. *A Guide to the Selection, Combination, and Cooking of Foods: Vols. I and II,* published in 1961, was co-authored with Jeremiah J. Wanderstock. The foreword, by Donald K. Tessler, describes the purpose of Rietz's project; "This is not a cookbook, but rather a detailed discussion of food preparation and cooking, with the intent of placing routine procedures on a truly scientific basis."(Rietz, 1961). The book's discussions pursued a rational structure for the measurement of taste. Through the presentation of the "Gustametric Master Chart," which was described as "a common logarithmic scaling system," the authors assigned a specific value to all foods in order to "determine quickly and exactly which combinations of foods make for agreeable meals." Although their attempts to measure taste were well intentioned, the many aspects of eating and cooking proved subjective and difficult to quantify.

Rietz was in the process of researching and writing an additional book about the science of taste at the time of his unexpected death on September 19, 1965. He died in his sleep at his San Francisco home, the victim of an apparent heart attack. Due to his untimely death, Rietz's intention to document his various collections and record his thoughts on food technology remained unfulfilled.

Collection Practices

Information on Rietz's collection practices is helpful in understanding how the Collection was assembled. The following is a short description of some of the acquisition practices that Rietz employed as a collector that is gleaned from the papers of his personal archive.

Rietz's extensive travel history was chiefly a product of the growth and expansion of Rietz Manufacturing. Rietz's choice of objects from specific cultures and locations was a result of where he happened to be traveling. Cultural representation within the Collection was not a product of deliberate collecting as much as it was a secondary aspect of his travels.

Rietz enlisted the assistance of antique dealers, traders, and other field experts in various parts of the world to act as his agent for locating and purchasing objects of interest. Thus, his primary source for objects was through the established antiquities trade of the places he visited. Rietz collected on several fronts simultaneously: Asian ceramics and snuff bottles, textiles, jade, kitchen antiques, artifacts of food technology, Egyptian, Roman and Greek antiquities, knives and cutlery, cookbooks, culinary illustrations, prints, and engravings. A common strategy of Rietz was to purchase whole lots of objects even though he may have been interested in only one or two objects within the group purchased. Rietz formed close relationships with curators and other museum and object professionals for guidance and legitimacy. He created several foundations to house and exhibit his various collections. At Mills College in Oakland, California he established the Mills College Asian Ceramics Collection in 1951, The Rietz Folk Art Center in 1952, as well as The Rietz Technology Foundation and The Food Artifacts of Man in 1958. He also donated a significant col-

lection of objects related to the history of medicine to the University of California at San Francisco.

From information gathered about Rietz's life and collection practices, it seems that his primary concern for collecting was education. He wanted to share knowledge of other cultures in the hope of illustrating the commonality of all cultures, his goal being to promote peace and cultural understanding through knowledge of others. He understood his collection of artifacts of food technology to be one of cultural comparison rather than cultural representation. He was not attempting to collect in order to illustrate the development of technologies related to food of one specific group through time. He collected what he happened upon or was offered, adding to a collection that he hoped would illustrate the universal attempt of humanity to appease hunger and thirst across all cultures and time periods.

The Technologies of Food

The Collection comprises objects concerned with the technology involved in the human interaction with food. The term "food technology" is broad and encompasses the processes and practices beginning with raw resources or ingredients, through intermediate stages of food preparation, to the final prepared food ready for consumption. The manipulation of food involves several stages, moving through a continuum of processes that are ongoing and simultaneous. These processes can be defined as the following:

1. The ingredients must be procured. This might be done through hunting, gathering, fishing or agricultural production;
2. The resulting resources often require preliminary processing. Initially, raw resources are modified in some way, i.e., grain is harvested and milled to flour; meat is butchered into manageable cuts;
3. These resources are distributed in some fashion and, perhaps, stored.
4. The preparation phase renders the raw foodstuffs into final products by any of a variety of methods such as cooking, fermenting, brewing, or distilling;
5. The food ready for eating is then consumed. This act may be simple or complex depending on the culture and occasion; and
6. The leftover foods and raw materials must be discarded or stored.

Each process involves specialized tools as well as specific techniques developed within the context of a particular environment and culture. These practices are often highly ritualized and invoke ceremony of some kind.

The processes described within the study of food technologies can be further distilled to involve the same basic operations for most cuisines:

1. Storing and transporting, which require containers of various shapes, sizes, and materials;
2. Preparation and cooking, which involve tools for techniques such as heating, chilling, cutting, mixing, separation, retrieving and turning, measuring, forming, brewing or fermenting;
3. Serving, which involves specialized objects and tools depending on cultural practices;
4. Eating and drinking, which may involve specialized tools as well as a multitude of cultural behaviors and rules.

The tools and material utilized in these basic operations are the basic artifacts of food technology.

Highlights of the Collection

The Collection is not a comprehensive collection of food technology, but objects in the

Collection illustrate most of the fundamental developments of the processes and practices associated with the human manipulation of food through time and across varied cultures. Common practices such as use of fire, cutting, serving and storing of foods are illustrated through objects from the first millennium BCE to the early 20th century. Objects made of clay, wood, bone, leather, metal, and glass originating from Ancient Palestine, Cyprus and Asia Minor, Arab-influenced Persia, Medieval and Renaissance Europe, Colonial North America, 19th century Japan and China, and Edwardian England and France illustrate the cultural development of technologies associated with preparing and eating food.

Mediterranean Terra Cotta and Bronze-ware

The oldest materials in the Collection are common unglazed terra cotta vessels from Ancient Palestine and decorated serving-ware from Cyprus (Fig.1). Dating from roughly the 10th to the 6th century BCE, the bowls, pots, and jars represent the forms of vessels used for storage, preparation, and serving of food and drink that would have been common during the Iron Age. These items were the most basic of tools of ancient cooking used at every meal and were often items of trade. Produced by Phoenician colonies on the coast and islands of the eastern Mediterranean, these objects were exported to the Levant and Egypt. Such common and ubiquitous trade goods underscored the shared cooking and eating technologies of differing cultures throughout the region. Their basic structure and function remained unchanged for millennia.

The Collection also contains bronze cooking vessels from Roman Palestine that date from the 1st century BCE to the 2nd century CE. Although badly corroded, they illustrate the shapes of cast metal cooking vessels of the period. Due to their cost, metal-cooking vessels would not have been used by common workers. These vessels represent the cooking technologies of a more affluent class of household.

Other objects in the Collection from the eastern Mediterranean are 5th century BCE Greek drinking vessels (Fig. 2). The cups and pitchers are highly polished with a rich black slip glaze. Used by the upper classes of Greek society throughout the Greek colonies of the eastern Mediterranean, these simple but stylized objects allude to the highly ritualized practice of drinking wine.

Persian Ceramics

Clay and ceramic materials from Persia, now modern Iran, comprise one of the largest groups of objects collected by Rietz. Numbering over a hundred objects, the rich tradition of Persian pottery is demonstrated in this collection with examples dating from the first century BCE to the late 19th century CE (Fig. 3). The bulk of the Collection dates from the Medieval Islamic period of the 11th–14th century CE. Objects from the major ceramic producing areas of Persia during this period, Kashan, Nihavand, Zenjan, and Rayy, are represented. Most of the objects are serving pieces with beautifully multi-hued decorative glazes and designs. Used by nobility and merchant classes, the size and shape of the platters, dishes, and bowls suggest communal sharing of food and drink and attention focused on matters of the table and eating.

Eating Utensils: Knife Collection

Numbering over 350 individual examples from Europe, Asia, Africa, and the Americas, and ranging from the early 16th century CE to the 20th century CE, this collection illustrates the variety, history and development of the knife in the Modern period. Knives are arguably one of the most important tools of the kitchen and the dining room. Together with containers and fire, knives remain

as necessary to a modern meal as they would have been centuries ago. Since most aspects of food preparation require their use, the story of the development of the knife is fundamental to Rietz, who understood its importance and primacy to the technology of eating and cooking. There is an obvious focus on their collection and an attention to the variety of uses to which they can be put. He collected kitchen knives, utility knives, carving knives, chopping knives, cleavers, cheese knives, fruit knives, scissors, folding knives, traveling knives, bread knives, and daggers. (Figs. 4 and 5) In the pursuit of cross cultural examples, he collected knives from Northern Europe (specifically England, Germany and the Netherlands) as well as Italy, France, Spain, Japan, China, Nepal, Ceylon, Afghanistan, Burma, India, Indonesia, Oceania, Africa, and the Americas.

Included with the knife collection are also examples of the historic development of the fork in the West and chopsticks from Asia (Figs. 6 and 7). Grouped as a chronicle of the development of eating utensils that carry food to a diner's mouth, the Collection is one of only a handful of collections of cutlery that clearly illustrates the evolution of tableware. Equally significant are the multiple examples of cutlery from major foundries and metal smiths, primarily of England and Germany, which are representative of the manufacturing processes of metal household goods during the entire Industrial Revolution.

The knife and cutlery collection is probably the best understood and documented area of the Collection. Examples of knives, forks and chopsticks have been exhibited frequently at the California Academy of Sciences and loaned to other institutions. The provenance for these objects is well documented and has been greatly enhanced through a collection survey conducted in 1982 by Bernard Levine.

German and Dutch Ceramics of 18th Century North America

The German and Dutch colonists who settled the rural areas of Pennsylvania and New York in the early 17th century were heirs to not only the cooking and eating traditions of their northern European homelands but also the cooking technologies as well. The Collection holds about fifty pieces of household ceramic containers used in preparing and storing food that reflect the traditions of the German and Dutch foodways in North America (Fig. 8). Produced mainly in the 18th century for common domestic purposes, these objects clearly reflect the influence of northern European ceramic traditions.

Hearth Tools

Open-hearth cooking is, simply, cooking over a live fire. This technique has been the dominant method of cooking since the realization that fire transforms food. Surprisingly, for such a basic activity, specialized tools for hearth cooking are a fairly recent phenomenon in most cultures. Typically, the only tools needed for cooking with fire were waterproof containers that withstood heat, and a tool with which to suspend either food or a container close to the direct radiant heat. Every culture has developed its variation on these two requirements, inventing cooking technologies based on materials at hand. Rietz seems to have collected with this fundamental idea in mind. Every culture/geographic area represented in the Collection has some example of tools used for hearth cooking, however the majority of hearth tools in the Collection are examples from the domestic cooking traditions of 18th and 19th century Great Britain and North America (Fig. 9).

English and French Measures

Dating from 18th and 19th century France and England, several examples of individual sets of measures used to verify a particular amount of liquid volume were collected by Rietz. Following

FIGURE 1. Terra cotta vessels from ancient Palestine. Clockwise from upper left: CAS 0389-0443, CAS 0389-0496, CAS 0389-0145, and CAS 0389-0495. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 2. Greek drinking vessels, 5th century BCE. Clockwise from center: CAS 0389-0188, CAS 0389-0097, CAS 0389-0263, and CAS 0389-0082. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 3. Persian ceramic serving-ware. Clockwise from upper left: CAS 0389-0272, CAS 0389-0651, CAS 0389-0666, and CAS 0389-0668. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 4. Knives used for chopping. Clockwise from upper left: CAS 0389-1255, CAS 0389-1079 A,B, CAS 0389-1229, and CAS 0389-1676. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 5. Knives used for cutting and grinding. Clockwise from center: CAS 0389-1147 A, B, CAS 0389-1099, CAS 0389-0469, and CAS 0389-0183. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 6. Cutlery. From left: CAS 0389-1639, CAS 0389-1642, CAS 0389-1823, CAS 0389-1826, CAS 0389-1869, CAS 0389-1875, CAS 0389-1876, CAS 0389-1884, CAS 0389-1886, CAS 0389-1921, and CAS 0389-1922. Photo credit: Dong Lin, California Academy of Sciences.

the needs of trade and commerce that erupted from the expansion of markets in the 16th–19th century in western Europe, reliable weights and measures were crucial to the accounting of foods and liquids as commodities. The measuring of both dry weight and wet volume became a matter regulated by the government to avoid theft and inaccuracy. Stamped with official governmental markings of France or England, the vessels in the Collection are cast of pewter and other metals and represent the measuring system of each individual country from which they originated. The measures are not graduated but are sets of containers of fixed value. The French measures employ the metric scale, each measure inscribed with its value: "Litre," "Demi-litre," "Deca-litre," etc. (Fig. 10). The English measures including some examples made of wood, employ the traditional English measuring scale, and are inscribed with values such as "quart," "pint," "half-pint," and "dram" (Fig. 11).

The measures were most likely used as tools of commerce to measure commodities such as milk and cream sold in public markets. Although they resemble modern household measuring cups, these objects predate the common use of household recipes and cookbooks that employed fixed amounts of ingredients. However, it is likely that these tools are an antecedent to household measuring devices.

19th Century Professional Cookware

Haute Cuisine or *Grande Cuisine*, the elite cuisine of 19th century Europe, was rigorously codified and communicated with the development of two written genres, cookbooks and culinary journals and magazines. By the middle of the 19th century, French *Haute Cuisine* had become identified with professional and culinary mastery throughout Europe as well as the United States. The success of this first "modern" style of cooking was dependent on two things: specialized tools and specialized labor. Militaristic in its organization and scientific in conduct, kitchens serving *Haute Cuisine* had clearly defined hierarchies of labor. Cooks specialized in various areas of the cuisine: pastry, sauces, roasting, cold service, hot service or butchering. All of these functions required tools tailored to the needs of each specialist. Known as a *batterie de cuisine*, these kitchen utensils were mass-produced by specialty purveyors of kitchen equipment in prescribed shapes and size. Two areas of the Collection illustrate the level of specialized technology developed for the production of *Haute Cuisine*: (1) an array of copper saucepots, kettles and pans manufactured in France in the later half of the 19th century for the English market (Fig. 12), and (2) a large collection of ceramic, glass, and metal molds or forms for the molding of jellies, aspics, creams and ice cream.

In greater detail, the first group includes a collection of copper cooking ware of about 35 individual objects. Most are flat-bottomed pots with long handles, indicating that they were intended for use on a large, flat-topped range rather than over an open fire. However, some have convex bottoms with a narrow flange 2–3 inches from the bottom for use in a range with direct exposure to the fire. The objects range in size with obvious graduation of volume. A set of six copper, long-han-

FIGURE 7. Chopsticks. From left: CAS 0389-1939A-D, CAS 0389-1940A-C. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 8. German and Dutch ceramics of 17th and 18th century North America. Clockwise from upper left: CAS 0389-0668, CAS 0389-0651, CAS 0389-0666, and CAS 0389-0272. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 9. Hearth tools. Clockwise from left: CAS 0389-1143, CAS 0389-1144 A,B CAS 0389-1145, CAS 0389-1146, and CAS 0389-1436. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 10. French measures. From left: CAS 0389-1200, CAS 0389-1204, CAS 0389-1205, CAS 0389-1259, CAS 0389-1260, CAS 0389-1271, and CAS 0389-1272. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 11. English measures. From left: CAS 0389-1190, CAS 0389-1178, CAS 0389-1443, CAS 0389-1192, and CAS 0389-1177. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 12. Clockwise from left: CAS 0389-0995, CAS 0389-0854, CAS 0389-1009, and CAS 0389-1074. Photo credit: Dong Lin, California Academy of Sciences.

FIGURE 13. Batterie de cuisine. From left: CAS 0389-0825, CAS 0389-0809, CAS 0389-0826, and CAS 0389-0810. Photo credit: Dong Lin, California Academy of Sciences.

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dled sauté pans lined with tin range in size from half of a quart to several quarts, their diameters expanding with the additional volume as they increase in size. A similar set of four sauce pans with lids, used for keeping sauces warm, are also made of copper with tin lining in graduated dimensions. Inscribed on the outside of each saucepan is the note: "Made in Paris for E. Bennet, 55 Dean Street, London W"(Fig. 13).

The second group of objects is a vast collection of molds and forms. These objects were developed for use in Europe during the late 18th century for elaborate cold buffets. Jellies and aspics, made from gelatin rendered from veal and pork, held a prominent position in the cuisines of the gentry and the middle class in Western Europe from the 16th century until the beginning of the 20th. It is hard to imagine the prominence and attention that molded jellies and aspics held in European formal cuisine from the late Renaissance, when the technique was refined, to the 19th century when the display of molded jellies on buffets took on an almost architectural grandeur. The intention was spectacle, a tradition carried over from the high dining of the Middle Ages when allegorical displays of food played a central role in royal banquets. As cuisine moved into the Industrial age, the manufacturing technologies of glass, ceramics and metal work became less costly and more sophisticated, offering the opportunity to greatly expand the shapes and sizes of molds.

The Collection contains a vast sampling of the differing styles, sizes and material of molds and forms. Most are 19th century of English and French manufacture. Shapes vary from geometric figures to almost life-like renderings of fruits, vegetables, and flowers. In addition to the jelly molds, there are also forms for molding butter, ice cream, almond milk, and custards. These molds are not rare because the fashion was so pervasive that mass production of molds guaranteed their ubiquity.

Significance of the Rietz Collection and Studies of Food

A basic question that arises in the course of studying the Collection is what meaning it has in the context of the broader study of cultural practices surrounding food. Nourishment is a necessity and, thus, it is reasonable to state that the human concern for food and its preparation has been and continues to be a primary human activity. For such an essential activity, there has been relatively little notice paid to the recording of the history and practice of this fundamental aspect of daily life.

The basic reason that this field of study has been virtually ignored until recently, is that philosophical tradition has tended to privilege questions about the rational, the eternal, and the abstract and to give less attention to questions about embodied, concrete, practical experience. Physical, transitory, and completely ordinary experiences like eating are considered less valuable because they distract from the pursuit of more abstract goals. Food has not been considered a topic worthy of scholarly attention because it has traditionally occupied the realm of women's work and the work of the under-classes of society, which have been traditionally ignored by Western scholarship. Western philosophies, like the cultures in which they emerge, historically have discounted the value of women's activities. Work has been defined in such a way as to exclude reproductive labor and unpaid activities in the home (Curtin and Heldke 1992).

Another barrier to the academic study of food is the fundamentally ephemeral quality of the everyday. The people of the past who performed the tasks of cooking and preparing food were largely illiterate. Knowledge of cooking was experiential and informed by an oral tradition. Cooks learned their skill through the direction of others and by rote practice. They left little record or description of the processes that occupied their days. The utilitarian nature of tools used daily and made of materials available at hand meant they rarely survived beyond their immediate use. Obsolete or flawed tools were discarded or reworked. Hence, little evidence remains and little documentation exists to explain their use.

The relegation of the study of the cultural and social aspects of food and cookery to the margins of history and social sciences has recently begun to reverse. The history and technologies of cooking and eating have begun to achieve marginal recognition in the last four decades as legitimate aspects of social sciences, history, and material culture studies. A growing body of research and writing has replaced the past trend of ignoring or marginalizing such study. Consequently, food studies have become more acceptable as the subjects of serious scholarly investigations. In the 20th century, the enormously influential historical school associated with the French journal *Annales: Economies, Societes, Civilisations* stimulated academic research into both the material and cultural conditions of everyday life. Marc Bloch and Lucien Febvre, scholars conversant with the new sciences of sociology, geography, psychology, and anthropology, started the journal in 1929. Through histories of ways of life and ways of thinking, from the Middle Ages to 1800, the journal focused on description of "economies, societies, and civilizations," such as the study of diet, ingredients, and food habits. More recently, the annual Oxford Symposium on Food and Cookery, founded by Alan Davidson and Theodore Zelden, has provided a forum and outlet for the growing body of research and writing about food and eating. This has led to additional symposia and academic journals devoted to the study of not only cooking and eating but domestic life in general.

Cultural anthropology has long recognized the social importance of food preparation and eating as a means of exchange and communication and as a means of expressing both social stratification and social solidarity. Classic debates have focused on systems of classification of edible and inedible animals and plants, the nature and logic of food taboos, the significance of ritual and ceremony in food practices, and the social role of food as an object of exchange (Levi-Strauss 1964; Simoons 1961, 1994; Douglas 1972; Mintz 1985; Richards 1939). In a parallel, but largely independent development, historians have increasingly been influenced by the approach of cultural anthropologists to the study of society. Ethnography has proved to be an invaluable tool for not only anthropologists but also cultural and economic historians as a method of investigating existing traditions and practices around food that echo those traditions of the past (De Certeau et al. 1998; Issac 1983; Hilliard 1972).

The sources used by historians and, to a lesser degree, anthropologists are generally archival documents such as correspondence, journals, diaries, wills, inventories, and the household accounts of individuals and institutions. These principal sources range in diversity and scope but remain problematic because so few people engaged in food practices were able to read or write (Theophano 2002). Until the middle of the 19th century, the majority of texts about food and cooking including cookbooks, menus, inventories, and manuals of etiquette, were written by and for those expressly not engaged in the actual work of obtaining and preparing food. These documents supply information such as how much of what ingredients were eaten by members of different classes at various times and places. They rarely record in detail how foods were prepared, due to the general assumption that basic knowledge of the kitchen and its technologies was understood (Wheaton 1983).

While many social historians assume the evidential priority of the written word, the study of objects or artifacts as primary source material has been a concurrent development in the fields of folklore, archaeology, and others engaged in the study of material culture (Glassie 1968; Deetz 1977). If the goal is to encounter and make sense of an alien mind and time, whether that of a 19th century English cook or a 9th century Persian gourmand, then complex material objects, such as tools or art, are crucial. These objects are whole texts, each one an objectification of thought, process, and tradition (St. George 1988). Culinary artifacts, thus, become more highly valued as primary source material since archives and published documents with references to food are rare, and meaningful descriptions of food preparation processes carried on by and for the less affluent classes are almost non-existent.

Conclusions and Prospectus

The Rietz Collection of Food Technology offers the opportunity to explore the technologies associated with food across a spectrum of multiple cultures and time periods. Although the Collection is not a comprehensive representation of any single tradition of cultural foodways, it does offer insight into numerous traditions. The collection is comprised of a series of small collections of artifacts and tools that have been developed within specific traditions. These objects have enormous potential to illuminate an area of human activity that lacks a substantial written record. Areas of potential research include the investigation into the relationship of ancient Mediterranean trade goods and the spread of food technologies; Islamic tableware, ceramics and the rituals of dining; the relationship between Colonial American food technologies and those of northern Europe from the 17th–19th centuries; the regulation of measurement in 18th century European domestic markets; as well as the widening gulf between the techniques and tools of the professional kitchen and those of the domestic cook in the 19th century. It is hoped that in the future more scholarly interest will be focused on the objects in the Collection.

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The History of Research at the California Academy of Sciences' Steinhart Aquarium and Department of Aquatic Biology

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Speaking on September 29th, 1923, the opening day of Steinhart Aquarium, David Starr Jordan of Stanford University said "the people of this city, the children especially, will look with wonder and profit on the hundreds of varied forms of fishes; the men of science will make use of them for extending our knowledge of marine life. The most famous aquarium in the world is the one of Naples. Not for its variety of fishes, for in this regard the Mediterranean cannot compare with Hawaii and the South Seas. It is, however, the center to which hundreds of naturalists all over the world have been drawn for most important studies." Since its founding, the Academy's Steinhart Aquarium has been dedicated to educating the public about its inhabitants and providing research opportunities to its staff, students, and visiting scientists.[1]

The unique facilities possessed by a large public aquarium such as the Steinhart allow research opportunities unavailable to most universities and research laboratories (Figs. 1–2). The diversity of living creatures, as well as the immense water systems, quality control and monitoring systems, which can duplicate various aquatic environments for controlled experimental studies, as well as the "green thumbs" possessed by the staff biologists, have resulted in both serendipitous and directed discoveries, as is evidenced by the resultant myriad publications. In that it is a division of the California Academy of Sciences, the Steinhart shares the same dedication to diversity in its research and display, and it has been recognized throughout its history for the comprehensiveness of its collection of macroinvertebrates, fishes, amphibians and reptiles, as well as aquatic birds and mammals.

With as many as 500–600 species on display, it has been a showcase for teachers and students of evolutionary biology. No other aquarium can boast living exhibits of every (except, alas, a coelacanth) major group of fishes, ranging from hagfish to lungfish and from *Abudefduf* to *Zalieutes*. It is no small coincidence that the first three directors of the Steinhart, Alvin Seale, Earl Herald, and I, trace their taxonomic training to David Starr Jordan, America's most famous ichthyologist and the President of Stanford University and the California Academy of Sciences. Alvin Seale was his student, and Earl S. Herald was also a Stanford graduate, having studied under George S. Myers, who earlier had been a student of David Starr Jordan, J.O.Snyder, and Edwin C. Starks, also at Stanford (see Walford 1970). Although I attended the Scripps Institution of Oceanography (the marine laboratory of Stanford's arch rival, the University of California), members of my doctoral thesis committee included Carl L. Hubbs (who, like George Myers, laid claim to having been Jordan's last student; Hubbs, like Myers, was also a recipient of the Academy's Fellows Medal) and Richard H. Rosenblatt (a student of Boyd Walker of the University of California, Los Angeles

[1] See McCosker (1999a) for an extensive history of the Steinhart Aquarium, and Leviton and Aldrich (1997) for the history of the early Academy.

FIGURE 1. Living adult specimen of midwater eelpout, collected at 600 m depth, and on display in the Aquarium. This was the basis of M. Eric Anderson's master's thesis and demonstrated the unique research opportunities provided by the Steinhart. Photograph by John E. McCosker.

FIGURE 2. Rooftop fish breeding laboratory in the early Steinhart. Photograph courtesy California Academy of Sciences.

[UCLA], who was a student of Hubbs). Seale, Herald, and I were thereby trained in systematic biology and much of our research careers involved studies of the relationships of fishes and the capture, identification, and naming of new species. Seale named 343 new species, mostly in co-authorship with David Starr Jordan; Herald named 23; and at the time of this writing, I am responsible for 93 new specific and 18 new generic names. Excluded from this paper's bibliography are the taxonomic works of Seale, Herald, and the author. Titles of publications involving those systematic studies are listed in Eschmeyer (1998).

The Steinhart's first director, Alvin Seale (1871-1958) (Fig. 3), was a colorful naturalist and explorer who surveyed much of the central and western Pacific, making collections for the Bernice P. Bishop Museum in Honolulu, for Stanford University, and for the Academy (CAS). Much of that material is now housed at CAS. Born in Indiana, he listened intently while David Starr Jordan spoke at his high school graduation. Jordan advised the students to "go where the masters taught," so Seale rode his bicycle across the country to enter Stanford in 1892. His education was interrupted by the Klondike Gold Rush and his tropical Pacific surveys, and he finally graduated in 1905. His later fisheries work in the Philippines and the creation of the Manila Aquarium was followed by an ichthyological curatorship at Harvard University's Museum of Comparative Zoology (MCZ), after which he retired to Santa Cruz, California in 1920. This is all recorded in his intriguing biography (Seale 1946) titled *Quest for the Golden Cloak*.

Seale's retirement was short-lived in that Jordan and then Academy director Barton Warren Evermann invited him to assist in the design of the new Steinhart Aquarium and to become its first Superintendent[2], a position he held until 1941. Seale's research interests were mostly in systematic ichthyology and fishery development. At the Aquarium, he was credited with the of fathering an industry centered on the brine shrimp (*Artemia salina*), a minute crustacean that existed in vast

FIGURE 3. Alvin Seale in his aquarium office. Photograph courtesy California Academy of Sciences.

[2] The formal title 'Director' of Steinhart Aquarium was first used in 1976. Seale was entitled 'Superintendent' and Herald was its 'Curator.' Photograph courtesy California Academy of Sciences.

quantities in San Francisco Bay. His findings were turned over to the San Francisco Aquarium Society (SFAS), founded in 1923, which subsequently marketed live brine shrimp to the growing popular aquarium industry. The SFAS became one of the aquarium's primary benefactors over the years, purchasing specimens such as the Amazon freshwater dolphins and supporting research projects and expeditions. Seale and his staff used their husbandry skills to facilitate the breeding of mosquito fish (*Gambusia affinis*) in order to help control that ubiquitous pest of the Central Valley. Aquarium collectors sampled throughout California and provided both display specimens and valuable data that now reside in the CAS research collections. Regretfully, few other research projects were undertaken during the Steinhart's early years largely because of fiscal and staffing limitations.

Upon reaching the age of seventy, Seale stepped down and was replaced by his assistant, Robert J. Lanier, who served as the Acting Superintendent from 1942 to 1944. Lanier was not a research biologist but studied tropical freshwater fishes, published in popular aquarium journals, and wrote a popular book with Ida Mellen, *1001 Answers to Questions About Your Aquarium* (Mellen and Lanier 1935). Lanier was followed by Wilbert "Wib" Chapman (1910–1970) who was trained in fisheries and systematics and who served CAS both as Curator of Fishes and Interim Superintendent of the Aquarium. Chapman also had a keen interest in tropical aquarium fishes and was responsible for rejuvenating the *Aquarium Journal*, the publication of the SFAS. During the war, Chapman was called to the Pacific to perform government service for the Office of Economic Warfare. The President of the Academy's report states "While details of his work cannot at present be divulged he brought back with him a very large collection of marine fishes which will prove a valuable addition to the Department's series." We now know that Chapman traveled the Pacific to set up local fisheries at island bases so that GIs could dine on fresh fish rations rather than dried haddock. He later became a fisheries advisor for the State Department and the Director of the Van Camp Foundation.

In 1945, Chapman was followed as the Aquarium's Interim Superintendent by John L. Kask, a Canadian fisheries biologist from the University of Washington. Kask's tenure lasted but a year as he was sent to occupied Tokyo on military leave to oversee the Scientific Investigation of the Fisheries Division. He was not involved in aquarium-related research activities. After he left the Steinhart to become head of the Pacific Oceanic Fisheries Investigation, he then moved on to became Director of Fisheries for Canada, and later became the head of the Inter-American Tropical Tuna Commission. Kask was followed in 1946 by Wilbur I. Follett (1901–1992), a lawyer by profession but a passionate ichthyologist by avocation. Bill was also the Academy's Curator of Ichthyology. And, finally, amidst the post-war turmoil, Academy Director Robert C. Miller (Director of CAS from 1935–1963) stepped in to run the Steinhart during 1947 and remained until August 1948, just weeks before the Aquarium celebrated its twenty-fifth anniversary. At that time, Earl S. Herald, a young Stanford graduate who had just returned from military service in the Philippines, was hired as the Aquarium's next Curator, a position he was to hold for the next quarter century (Myers et al. 1974; McCosker 1999a, 2003).

As mentioned earlier, Earl was a product of Stanford and a student of George Myers. His systematic interests concerned syngnathids, the subject of his Ph.D. thesis, but those interests rapidly broadened to include fishes and invertebrates of San Francisco Bay, the population dynamics of elasmobranchs, the biology of freshwater dolphins, and the experimental design and operation of aquatic systems. Much of Earl's career at the Steinhart was devoted to the improvement and ultimate rebuilding of the aquarium, aided in large part by his successful career as the host (from 1952–1966) of the Academy's popular television program, *Science in Action*. Nonetheless, he found time for research and published a number of important works (Fig. 4). Assisted by his wife Olivia ("Pinkie"), and Steinhart secretaries Phyllis Ensrud and Judy McClennahan, he was a prolific

FIGURE 4. Robert Dempster (left) and Earl Herald (right) in the Aquarium's chemistry/pathology laboratory. Photograph courtesy California Academy of Sciences.

writer, participating in the creation of many of the 626 *Science in Action* episodes and authoring 93 publications, mostly scientific, and three books, *Living Fishes of the World* (Herald 1961) (translated and published in eleven languages), *Fishes of North America* (Herald 1972), and the Peterson *Field Guide to Pacific Coast Fishes* (Eschmeyer, Herald, and Hamman 1983).

Herald was eager to add marine mammal display facilities to the Steinhart. Marine and freshwater cetaceans provided research opportunities, as did the serendipitous arrival of an Amazon Manatee (*Trichechus inunguis*). Dubbed "Butterball" (Fig. 5), it resided in the aquarium for 17 years. It made history as one of the few *T. inunguis* ever in captivity and participated in two masters' theses and two doctoral dissertations, as well as six research publications ranging from hematology to chromosomes to vocalizations. Earl's interest in freshwater dolphins led to the capture and display of several Amazonian boutu (*Inia geoffrensis*). They did not survive well in captivity and were susceptible to diseases, which were identified and studied by Stewart Madin, the Aquarium's consulting veterinarian (Pier and Madin 1976). Earl attempted to achieve another Steinhart first with the capture and display of a susu, the blind river dolphin (*Platinista gangetica*) of the Ganges, Indus, and Brahmaputra river systems of southern Asia. Susu were known from the time of Pliny the Elder (72 AD), who wrote about their curious anatomy and the muddy rivers that they inhabited. Earl and associates Robert Brownell (Fig. 6), Frederic Frye, and Elkan Morris obtained three susu while on expedition to Sukkar, West Pakistan, but then they were faced with the formidable task of transporting them half way around the world. Returning with them via Karachi, they made a brief rest stop and left the dolphins in a clearwater swimming pool. There, the researchers were

FIGURE 5. Butterball, the Amazonian manatee that lived 17 years in the Steinhart and was the subject of numerous research projects. Photograph courtesy California Academy of Sciences.

apparently the first to discover that these dolphins swim on their sides, a unique and curious adaptation. The rigors of capture and transport were such that none of them survived for long; however, the results of Herald's research concerning susu anatomy, swimming behavior, and echolocation were published in 1969 as a cover story in *Science* magazine.

Incorporated into the Steinhart's 1963 rebuild were seawater holding facilities and a small laboratory that facilitated research. Visiting researchers and their students used the Steinhart displays and new facilities for studies of *Artemia salina* (by Sarane Bowen of San Francisco State University [SFSU] and her graduate students), immunological reactions of shark blood (by Ben Papermaster of University of California, Berkeley [UCB]), the response of the elasmobranch cardiovascular system to drugs (T.N. Burbridge and S.J. Feinglass of the University of California San Francisco [UCSF]), and the growth of sand dollars (J. Wyatt Durham of UCB). Additional holding facilities were built on the Aquarium's roof for studies of the schooling of clupeoid fishes by Anatole Loukashkin and his associates. The Academy's first biochemical systematics laboratory was installed off the hallway separating the Department of Herpetology from the Aquarium's engine room. In that lab, Earl and Academy herpetologist Alan Leviton and his associates investigated the plasma proteins of elasmobranchs, while Leviton and students pursued additional studies of salamanders and toads, as well as the ontogeny of reptile venoms (e.g., Leviton et al. 1964).

I followed Earl Herald in 1973 as the Aquarium's third long-term director after Earl's untimely death in a diving accident in Mexico. Trained as an evolutionary biologist with a specialization in fish systematics, I broadened my research interests at the Aquarium to range from a combination of field and laboratory studies of aquatic animal evolution and behavior, to microscopic bioluminescent bacteria to macroscopic man-eating elasmobranchs. I held the position of Director until

FIGURE 6. Robert Brownell (left) and Earl Herald (right) returning to San Francisco with a living susu. Studies of the captive susu resulted in a cover article in *Science*. Photograph courtesy California Academy of Sciences.

1994, at which time I became the first occupant of the McCosker Chair of Aquatic Biology. The Academy's research Department of Aquatic Biology officially arose at that time when the Chair of Aquatic Biology was established. Supported by gifts and grants from foundations and individuals, it has been located within the Academy's research Department of Ichthyology. Previous references to the Academy's Department of Aquatic Biology (the title first appeared in the 1940s) concerned the public exhibition function of the Steinhart Aquarium.

Shortly after my arrival in 1973, I discovered that the holy grails of the aquarium profession were the maintenance of a living coelacanth (*Latimeria chalumnae*) and a white shark (*Carcharodon carcharias*). Neither had been successfully kept in captivity and both provided unsurpassed research opportunities. Earl Herald and other aquarium directors had tried but failed in solving the capture and transport dilemmas of both species. Herald made an unsuccessful attempt to obtain permission to collect a living coelacanth at Grande Comoro Island in the far western Indian Ocean. His redesign of the Steinhart in 1963 saved the central tank for a living *Latimeria*. The Comores had been a French colony but in 1974 were soon to be granted independence. Working with filmmaker Al Giddings, algologist Sylvia Earle, pathologist Michael Lagios, Danielle Robineau of the Muséum National d'Histoire Naturelle of Paris and others, an American-French expedition team was quickly assembled that would attempt to film and capture a specimen (see McCosker and McCosker 1976). A preliminary survey team set out in October 1974, and it was followed by the expedition, which ran from January to March 1975. Although the expedition did not

capture a living coelacanth, one effect of a drought that had spread across East Africa, it did return with two frozen coelacanth specimens that had been previously captured, living specimens of flashlight fishes (family Anomalopidae) for the Aquarium, and large collections of preserved fishes, invertebrates, and algae that had been collected by divers between the surface and -75 m. Those materials resulted in the description of numerous new taxa, range extensions, and behaviors. And, in recognition of the importance of our work, then-president Ahmed Abdallah had a postage stamp printed that commemorated the Academy's expedition. One of the frozen *Latimeria* specimens was sold to the Scripps Institution of Oceanography for research and display and fresh tissues of the remaining CAS specimen were made available to researchers associated with a legitimate society having the odd name of Society for the Protection of Old Fishes (SPOOF), resulting in numerous publications, which inspired phylogenetic controversy and progress in the understanding of coelacanth phylogeny (see McCosker and Lagios 1979 and papers by Lagios and Compagno) (Fig. 7).

Among the discoveries made during the 1974/1975 coelacanth expedition was the first capture of living flashlight fishes (family Anomalopidae) from east Africa. Living specimens of *Photoblepharon steinitzi* were returned to the Aquarium and provided visitors an opportunity to observe bioluminescence and research biologists including Jim Morin of UCLA, Kenneth Nealson, and Margo Haygood of the Scripps Institution of Oceanography, and Yaye Herman, Ed Miller, and me of the Steinhart staff with an opportunity to study the behavior of these rare fishes and the symbiotic bacteria that illuminate them (McCosker 1977a).

Attempts to maintain a living white shark involved several Steinhart staff, including David Powell (previously of Sea World, San Diego, and subsequently with the Monterey Bay Aquarium), John Hewitt, Ed Miller, and others. A reward was offered to fishermen who accidently caught juveniles in their gill nets if they would follow a protocol that we had developed to minimize the trauma to the shark until our arrival (see McCosker 1981b; Ellis and McCosker 1991a). After several unsuccessful attempts, a young female was snared in 1980 off Bodega Bay and survived the capture, transport, and introduction to the new Roundabout facility. Our initial success was complicated by the discovery that white sharks are extremely sensitive to weak electrical discharge (Merkel and McCright 1985) in this case due to an electrical leak that was grounded in the tank, and the shark was subsequently returned while alive to the Farallon Islands (Figs. 8, 9). Other studies of white sharks by the author and students in Chile, Australia, Baja California, and at the Farallon Islands involved their life history, thermal physiology, and feeding and attack behavior (Tricas and McCosker 1984; McCosker 1985a; Tricas 1985; McCosker 1987a; and papers by Goldman et al.). With Robert Lea of the California Department of Fish and Game (CDFG), I documented all previous and recent white shark attacks in the eastern Pacific Ocean (McCosker and Lea 1996, 2006). Much of the research accomplished by the staff has appeared in a series of documentary films (broadcast by NOVA, BBC, National Geographic, and others) that have changed our understanding of white shark behavior and helped to formulate public safety policies for coastal waters and create legislation to protect that species. And, as a result of our studies, white shark behavior is now explainable and somewhat predictable, providing recreational ocean users with lifesaving advice.

Also bridging the gap between research and public education was the Aquarium's experience with the loud humming sound that troubled houseboat owners of Sausalito, Richardson Bay during 1985. The monotonous drone was a mystery until a SFSU biologist and Academy Fellow, Tom Neisen, suggested that the source might be a fish. The Aquarium, at the request of the Marin County Noise Abatement Bureau, ultimately demonstrated to an incredulous public that it was caused by mating midshipman (*Porichthys notatus*, also called humming toadfish) (Fig. 10), of the family Batrachoididae (McCosker 1986a, 1986b).

My taxonomic research at the Academy has primarily concerned the snake eels (family

FIGURE 7. One of two coelacanths captured at Isle Grande Comore during the 1975 CAS Expedition. This specimen was dissected by Michael Lagios (second from the right) and several other researchers and the results were published in the 1979 volume entitled *The Biology and Physiology of the Living Coelacanth*. Photograph courtesy California Academy of Sciences.

FIGURE 8. Sandy, the white shark that resided in the Roundabout in 1980, allowed the discovery of the extraordinary electrosensitivity of the species. Photograph courtesy of Al Giddings.

Ophichthidae), which were the subject of my dissertation. Subsequent work has involved revisions and descriptions of new taxa of moray eels (family Muraenidae) and of several other families. The eel work provided an important dimension to the understanding of bony fish evolution. These successful but poorly-known groups have, through their evolution, become specialized through anatomical reduction rather than elaboration.

I have continued in the Academy's century-long tradition of Galápagos studies (Fig. 11). The insular endemism of the ichthyofauna is not unlike that of the terrestrial fauna. Colleagues and I made numerous collections and studies using scuba as well as deepwater submersibles to 1000 m depth. As Chief Scientist for expeditions funded by the Discovery Channel (1995) and by IMAX (1998) involving the research submersible *Johnson Sea-Link*, I was able to capture 30 new species of fishes and many new invertebrates, as well as numerous new records and the addition of two fish families (Myrocongridae and Anguillidae) previously unknown from the Galápagos. Other expeditions to Cocos Islands (eastern Pacific), Cuba, Indonesia, New Guinea, Melanesia and Micronesia resulted in the capture of additional new fish species.

Numerous research opportunities arose within the Aquarium's pathology and water quality laboratory as Jordan had predicted on opening day. Many discoveries in aquatic animal husbandry were made in the Steinhart lab, and were later adopted in aquaculture and aquarium practice. As mentioned previously, Seale was also involved with the development and utilization of brine shrimp as an aquarium food stock, with later important contributions made by staff biologists Maurice Rakowicz and Robert P. Dempster (Fig. 4). As Curator and Pathologist, Dempster (at CAS from 1941–1990) was responsible for aquarium prophylactic medication such as the now universal treatment with copper sulfate to counter *Oodinium* parasites. Dempster worked with Mel Donaldson, a Bay Area physician who served in the veterinary lab and performed an important study of the

FIGURE 9. The author feeding a temperature-sensitive transmitter to a white shark off South Australia. Photograph courtesy of Al Giddings.

FIGURE 10. Juveniles of the humming toadfish. Steinhart researchers demonstrated that this species was the source of the bothersome noise in San Francisco Bay. Photograph courtesy of Ken Browning.

effects of cyanide collecting of reef fishes, and published a seminal work on flagyl as a treatment for amebiasis (Donaldson et al. 1975). Herald worked with Dempster on several projects and also studied and promoted the ultraviolet sterilization of seawater for aquarium systems. In a seminal serological study, Herald, Academy herpetologist Alan Leviton, and Dempster examined the role of albumin in the osmolality of captive elasmobranchs (Herald et al. 1970). Other discoveries often had serendipitous results that improved aquarium standards and practices, as occurred during parasitologist John D. Mizelle's (Sacramento State University) visits to the Steinhart. By bathing live fishes in a very dilute formalin bath, he was able to collect ectoparasites without injury to the hosts. Many of these were described as new taxa. The practice then became standard within the quarantine protocol for all incoming fishes. Dempster's successor, George Blasiola (at the Aquarium from 1973–1979), developed the use of quinaldine sulfate as an anaesthetic while he assisted Dempster with water chemistry and pathology. He was followed by Patricia Rainford Morales (at CAS since 1978 but now retired), who had studied and published upon a variety of treatments and conditions, including tuberculosis in fishes, manatees, and reptiles.

Other staff research accomplishments involving aquarium husbandry practices included those of Christina Slager (maintenance of chambered nautilus and the breeding of jackass penguins), followed by Pamela Schaller who continued in the penguin breeding projects; David Powell, John Hewitt, and Edward Miller (maintenance of white sharks); propagation of living coral reefs (Martin Wisner, Lloyd Gomez, and Bart Shepherd); the captive breeding of bushmasters (*Lachesis muta*) by Karl Switak; the breeding of numerous cichlid and other freshwater fish species by Francis Glennon; the breeding of lingcod (*Ophiodon elongatus*) by Robert Dempster and William Rohrs; and the husbandry and breeding of threatened, or rare and endangered species in captivity, includ-

FIGURE 11. The author about to descend to 1000 m off the Galápagos in a submersible. Photograph by John E. McCosker.

FIGURE 12. Jorge Gomezjurado in the Aquarium's seahorse-rearing laboratory. Photograph courtesy California Academy of Sciences.

ing the Pahrump killifish (*Empetrichthys lates*) by Alfred Castro, Pacific giant seahorses (*Hippocampus ingens*) by Jorge Gomezjurado (Fig. 12), red-legged frogs (*Rana aurora*) by Richard Lacer and Ed Ely, and Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*) by David White (Fig. 13).

Several Aquarium staff published numerous articles in popular journals such as the *Aquarium Journal* and the *Drum and Croaker*. Although not the result of their technical researches, it represented their knowledge, wisdom and their passion, and helped educate a large and devoted audience. (The references for popular articles are not included in this article's bibliography.) Herald, Dempster, Switak, Glenn Burghardt, this author, and others actively appeared in those and other journals, but the peerless publisher was Aquarium Collector Donald A. Simpson. Employed from 1945-1961, he published 59 articles on a variety of species and their behaviors, with intriguing titles ranging from "Pantodon keep Don panting" to "Tunnel of love — blind gobies!"

Since its beginning, the Aquarium has had an excellent relationship with the California Department of Fish and Game. Alvin Seale and his staff advised the department about husbandry matters associated with hatcheries and often received specimens for display. John Fitch, the director of the CDFG's State Fisheries Laboratory and a world's expert on fish otoliths, benefitted from the ear bones that were saved for him whenever an exotic fish passed on. Dempster shared his knowledge of parasitology and fish nutrition with the CDFG on a variety of projects. The disappearance of the California sardine (*Sardinops caerulea*) from Monterey Bay in the 1950s motivated the CDFG to begin a series of studies into the life histories of that species and the northern anchovy (*Engraulis mordax*). Between 1950 and 1970, the California Cooperative Oceanic Fisheries Investigations (CALCOFI) supported Anatole S. Loukashkin and other Academy researchers who performed studies concerning the behavior of those important species. In 1991, the Sacramento River winter-run chinook salmon were found to have decreased from historical levels

FIGURE 13. David White (center), manager of the winter-run chinook salmon project, examines a juvenile specimen. Photograph courtesy California Academy of Sciences.

of hundreds of thousands to 191 individuals. Relying on the facilities and skills of the Steinhart Aquarium and its staff to maintain a captive population, and the expertise of geneticists at the UC Bodega Laboratory to maximize the fish's genetic diversity, CDFG and federal agencies asked us to warehouse some of what remained of that endangered population, and the UC lab to develop the technology to genetically identify individuals and stocks. Between 1992 and 2002 we did so, dramatically increasing their number (to several thousand) and probability for survival, educating the public through displays and other educational activities, and designed rapid allele assessments that for the first time identified stocks to allow critical decisions to be made. Konstantin Karpov, a marine biologist at the CDFG Fort Bragg office, developed rockfish (*Sebastes* spp.) tagging techniques within the Aquarium's displays. And, at the request of CDFG, I performed a study (McCosker 1989a) of the inherent dangers of live freshwater eels (*Anguilla* spp.) in California, which became the basis of legislation disallowing their importation. Numerous articles have been published by Aquarium staff in the Department's fine journal, *California Fish and Game*.

Other researchers and agencies have taken advantage of the Aquarium's resources. The following is but a short and incomplete list that demonstrates the variety of those projects. Mwenda Kudumu, a research biologist at the NOAA Tiburon Laboratory, studied the growth of lingcod (*Ophiodon elongatus*) within the Aquarium's displays. Michael Lagios of UCSF and Children's Hospital, San Francisco, investigated primitive and euryhaline fish physiology and anatomy, and was an active member of the 1975 coelacanth expedition. Syd Kraul of the University of Hawaii and Steinhart biologist Edward Miller raised pelagic fishes such as yellowtail (*Seriola lalandi*) and mahi-mahi (*Coryphaena hippurus*). Norman Buell of the National Association of Corrosion Engineers and Ed Miller investigated the weak electric fields within the Roundabout tank relative to shark behavior. Ellen FitzSimmons-Porzig, a professor of human biology at Stanford University,

and her students employed video techniques to photograph living fishes for her research on "Virtual Vertebrates." Aquarium Research Associate William Bennetta and the author solved an eel problem for the Chevron Corporation, which had attempted to reconnect deep sea oil rigs in the Mediterranean. They were thwarted by the presence of large conger eels that had inhabited the pipes; we developed a chemical mixture that repulsed the eels without harming fish or pipe fitters. CAS Associate Larry Eng investigated the invasion of exotic *Corbicula* clams into the Delta-Mendota Canal system. Nancy Baum and Doug Conklin of the UC Bodega Bay laboratory established the absence of gulonolactone oxidase enzyme in their study of ascorbic acid synthesis in osteoglossid bonytongues. Les Timpe and Kathy Logee from the UCSF School of Medicine examined pacemaker currents in ventricular and atrial mRNA of sharks. And (see above) researchers from numerous laboratories benefitted from the tissues of the frozen coelacanth (*Latimeria chalumnae*) that returned with the 1975 expedition.

Several research projects undertaken in the Aquarium involved its plumbing rather than its living collection. In the mid-1970s, with energy consumption recognized as a national concern, the heating, circulation, and illumination of aquarium displays were carefully examined. A number of efficiency measures were undertaken after studies were performed by Pacific Gas and Electric, Interactive Resources Inc., the City's Bureau of Architecture, and FAFCO Solar, resulting in numerous savings and the first installation of a passive solar pass-through aquarium water heating system (McCosker and Tucker 1982). The heated aquarium water was recirculated through the rooftop glazed solar collecting panels and saved the equivalent energy needed to heat 20 San Francisco homes. And even better, the fishes became more amorous in the springtime with increasing solar activity. A spinoff of that project involved the Governor of California's Energy Advisor and Steinhart Research Associate Wilson Clark, who with this author studied "*Dispersed, decentralized and renewable energy sources as alternatives to national vulnerability and war*" (Clark and McCosker 1980) for the US Defense Civil Preparedness Agency. Other projects, such as Dow Chemical's testing of reverse osmosis membranes using Steinhart's various seawater systems, benefitted the scientific and industrial communities.

Many students from San Francisco State University (SFSU), Moss Landing Marine Laboratory (MLML), and beyond have received their graduate degrees working at or closely associated with the Steinhart. Several are particularly noteworthy. M. Eric Anderson, currently one of South Africa's leading ichthyologists, was a MLML student whose thesis concerned the deep sea creatures of the Monterey Canyon. He spent several years experimenting with the husbandry of living deep sea fishes, resulting in his masters degree ("Systematics and natural history of *Lycodapus mandibularis* in California waters" 1977) and the first public display of marine deepwater eelpouts (*Melanostigma pammelas*), which had been captured at a depth of 600 m (McCosker and Anderson 1976). Kenneth J. Goldman, a staff biologist and student at SFSU, received his MS in 1996 for a project entitled "Thermal physiology and behavioral ecology of white sharks, *Carcharodon carcharias*." The design and testing of his telemetric tracking equipment occurred in the Steinhart's tanks, resulting as well in studies of the thermoregulatory activity of California yellowtail (*Seriola lalandi*), giant seabass (*Stereolepis gigas*), and sevengill sharks (*Notorynchus cepedianus*). Other masters theses included Todd W. Anderson's "Identification and development of nearshore juvenile rock fish" (1983); Brooke S. Antrim's "Habitat and food resource utilization of three species of embiotocids in Elkhorn Slough, Monterey Bay, California" (1981); Candis L. Cooperrider's "Toxicity and sublethal effects on fish behavior of the antibiotic, Tylosin" (1982); Leon E. Hallacher's "The comparative morphology of extrinsic gasbladder musculature in the scorpionfish genus *Sebastes*"; Carol A. Wolf's "Reproductive behavior of captive yellowhead jawfish, *Opistognathus aurifrons*" (1982); David A. Ebert's "Aspects of the life history of California's two cow-

shark species, *Notorynchus cepedianus* and *Hexanchus griseus*" (1984); Leslie A. King's "Adult and fetal hemoglobins in the swell shark, *Cephaloscyllium ventriosum*" (1992); Cheryl R. Aday's "Environmental enrichment for dolphins and seals" (1993); and Gabrielle J. Goffinet's "Play behavior in the natural history of captive, black-footed penguins, *Spheniscus demersus*" (1994). Several doctoral dissertations have been based on Steinhart specimens or used other of its resources, such as Gerald T. Todd's (UCLA) "Evolution and the problem of buoyancy in cartilaginous and bony fishes" (1981), Samuel M. Taylor's (UCB) "Understanding processes of informal education: A naturalistic study of visitors to a public aquarium" (1986), and Margo G. Haygood's (UCSD) "Iron regulation of luminescence: Implications for the ecology and symbiotic associations of the luminous bacteria" (Fig. 14) (1984), and others such as Eric Anderson (UCSB), and Fred Schuierer (Stanford).

Subsequent to the Loma Prieta earthquake of 1989 and other temblors in California and elsewhere along the Pacific rim, the staff and trustees of the Academy recognized the need for major seismic reinforcement and rebuild of portions of the Academy, particularly its aquarium. After several studies and deliberations, the decision was made to demolish and rebuild all of the buildings that housed the California Academy of Sciences and its Steinhart Aquarium. The architectural firm of Renzo Piano was enlisted to provide the plans for the new Museum facilities, and planning for the new Steinhart was begun by Academy staff, led by its then-Director Robert Jenkins, and consultants. Jenkins left the Academy in 2004 and I undertook the helm until Dr. Chris Andrews, formerly the Director of the South Carolina Aquarium in Charleston, was hired in 2005. At the time of this writing, the new museum is largely constructed, and it and the Steinhart Aquarium are expected to reopen in late 2008. The new museum will incorporate vastly improved research laboratories for the Aquarium and the Department of Aquatic Biology. The new facilities will allow staff, students, and visiting researchers unique opportunities to continue the study of the aquatic denizens of life on Earth. David Starr Jordan would be proud.

FIGURE 14. *Kryptophanaron alfredi*, the forgotten flashlight fish, on display at the Steinhart and the subject of several research projects. Photograph courtesy of Ken Lucas.

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History of Invertebrate Zoology at the California Academy of Sciences

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From its inception as an institution in 1853, the California Academy of Sciences has maintained a strong interest in invertebrate zoology, irrespective of the fact that the integrity of a separate department of invertebrate zoology has only existed for part of the institution's 150-year history. Although the Academy's natural history collections and library were almost completely destroyed in the San Francisco earthquake and fire of 1906, rapid re-growth and expansion occurred during the 20th century.

Today, the California Academy of Sciences maintains four distinct collections in the Department of Invertebrate Zoology and Geology: recent invertebrates (both wet and dry collections), fossils (predominantly invertebrate), diatoms (both fossil and recent), and minerals.

The department houses approximately half a million specimen lots of recent invertebrates representing worldwide geographic scope but with emphasis on the Pacific Basin and the Indian Ocean. The collections are mostly from the marine realm, but also well represented are mollusks and crustaceans from freshwater and terrestrial habitats. The taxonomic groups represented by the largest segments of the collections are sponges, coelenterates, mollusks, crustaceans, echinoderms, and urochordates.

Historically significant collections currently maintained by the department include those of John Steinbeck and Edward Ricketts from the 1940 Gulf of California Expedition, which formed the basis for the book *The Sea of Cortez*. Other collections are from Hopkins Marine Station, the Natural History Museum of Stanford University, and the University of California, Berkeley, as well as the 1921 *Silver Gate* Expedition, 1932–1938 *Zaca* Expeditions, the U.S. Navy-sponsored *Mulberry* Continental Shelf Survey of 1949–1950, the 1953 *Orca* Expedition, and the 1964 Galápagos International Scientific Project.

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Invertebrate zoology, the study of animals without backbones, traces its roots in western societies to the marine studies of the Greek philosopher Aristotle (384–322 BC). However, it has only been since the first half of the nineteenth century that our understanding of the biology and evolutionary relationships of these often beautiful or seemingly strange and cryptic organisms has flourished.

The invertebrates represent a paraphyletic assemblage of staggering proportions. As a 1980 California Academy of Sciences in-house report stated, "The lumping together of all animals without backbones into a single heterogeneous group, The Invertebrata, is more an anthropomorphic anachronism than a scientific actuality." Pearse et. al. (1987) state, "Nearly two million species of living organisms have been described and named. The actual number may be closer to 10 to 20 million...most species of living things are multicellular organisms in the Kingdom Animalia." Only about 4–7% of the animal kingdom is composed of vertebrates (one part of one phylum), thus leaving the study of the other approximately 95% (representing all of the more than 30 presently recognized phyla) to invertebrate zoologists (Williams 1996; Brusca and Brusca 1990). Approximately one million species of invertebrates have been described, with estimates of five to thirty million more still undescribed at present (Wilson 1988). In 1875, Alfred Russel Wallace wrote concerning his book on zoogeography, "I think I must call the Book, - 'The Geographical Distribution of Land Animals' or the dredging men will be down upon me, for leaving out the 'most important part of the animal kingdom' etc. etc." (Raby 2001:215).

Paradoxically, most natural history research institutions and university biology departments devote more faculty, facilities, and curriculum to vertebrate zoology than to invertebrate studies. As an example of this, only two Academy research departments are currently dedicated to the study of invertebrate animals — Entomology, and Inverterbrate Zoology and Geology (IZG), while no less than five departments are committed to vertebrate zoology — Ichthyology, Aquatic Biology, Herpetology, Ornithology and Mammalogy, and Anthropology.

Nevertheless, the California Academy of Sciences has been actively involved in research regarding invertebrate zoology since the founding of the institution in 1853, over one hundred and fifty years ago. Much of what we know concerning the history of invertebrate zoology research at the Academy is contained in unpublished departmental reports (Anonymous, ca. 1980: Anonymous, ca. 1985; Chivers 1978; Miller 1960a, b; Rodda 1987; and Smith 1964). In addition, relevant events that occurred from the period of the Academy's founding to the time of the great San Francisco earthquake (1853-1906), are documented in Leviton and Aldrich (1997).

The Conchologists (1853-1970)

The close association between the disciplines of Geology and Invertebrate Zoology goes back to the early days of the Academy when invertebrate collections made from living material were accumulated mostly as comparative resources to supplement the fossil collections. During the mid to late nineteenth century, invertebrate paleontology and conchology (or malacology) did not present hard and fast disciplinary boundaries, as several notable conchologists were authorities in both disciplines. Included here were two Civil War veterans John B. Trask and James G. Cooper (Figs 1A–B). As a result of the initial efforts by these two productive individuals, a tradition of research in malacology and paleontology has been subsequently established at the Academy, with such work continuing to be published.

No less than ten curators aligned with paleontology and geology at the Academy have used conchology in their research, collected and compared fossil and recent shells, or have studied living mollusks as part of their research programs. These curators will be treated in greater detail in forthcoming paper on the history of geology at the Academy. Thus, only their contributions to invertebrate zoology at the Academy are discussed here.

John Boardman Trask (1824–1879) (Fig. 1A), one of the original founders of the Academy, discovered the first Cretaceous fossil from the new state of California (Trask 1856). Throughout his association with the Academy, he served variously as Curator of Conchology, Curator of Geology and Mineralogy, and Curator of Radiata, as well as being a founder and life member of the Academy. In addition to his work on fossil and recent mollusks, Trask (1857) also described new taxa of Pacific coast invertebrates including hydroids and bryozoans (Fig. 4A, D). A good account of Trask and the Academy is found in Leviton and Aldrich (1982, 1997).

Lewis Warrington Sloat (1815–1886), an amateur conchologist and a fellow founder of the Academy along with John Trask, was the original recording secretary of the Academy, and was elected Curator of Conchology in 1856. Sloat's contribution of a cabinet of mollusk shells from Baja California served as part of the core that began the Academy's collections. A brief biographic sketch of Sloat is that of Hertlein (1956:7). In that biography, Hertlein describes the influence to the Academy by Sloat the amateur conchologist, "No doubt the Secretary's interest in this field was a contributing factor in the Academy's decision to accumulate a collection of shells, which activity began with the inception of that institution and has continued to the present day, interrupted, unfortunately, by the total loss of the collection during the earthquake and fire in 1906. A few years after the founding of the Academy, Sloat went east, and little is known of his subsequent activities, nor is any photograph of him available in any biographical notice."

James G. Cooper (1830–1902) (Fig. 1B) contributed seminal works on the biogeography and systematics of western North American marine and terrestrial gastropods (Cooper 1886–1887). He published more than forty papers on malacology from 1859 to 1896, and is credited with the discovery of at least one hundred and sixteen new molluscan taxa. He was praised in writing by the noted malacologist and contemporary of Cooper's, Philip P. Carpenter, as a "zealous zoölogist." (Raymond 1902:75.) Cooper subsequently became the Academy's director, as well as a curator of recent and fossil shells. A biography of Cooper by W.O. Emerson was published in 1902.

William More Gabb (1839–1878) (Fig. 1C) was a member of the California State Geological Survey during the 1860s, which was headed by Josiah Dwight Whitney. This period coincided with the American Civil War, in which distant California was happily excluded from the military conflict. Gabb was elected Curator of Paleontology at the Academy on 6 January 1862. His appointment occurred at the same meeting at which John Trask was elected Curator of Conchology and James Cooper was elected Curator of Zoology. Gabb published on fossil and recent mollusks,

FIGURE 1. Conchology and Invertebrate Paleontology at the Academy. A. John B. Trask. B. James G. Cooper. C. William More Gabb. D. Robert Edward Carter Stearns. E. Josiah Keep. F. Frank Marion Anderson. G. Roy Ernest Dickerson. H. G Dallas Hanna. I. Leo G. Hertlein. Photographs courtesy Department of Invertebrate Zoology and Geology, California Academy of Sciences.

Cretaceous formation subdivisions in California, and other invertebrate groups such as pennatulacean coelenterates (Gabb 1862, 1864) (Williams 1999:25, 27).

Robert Edwards Carter Stearns (1827–1909) (Fig. 1D) served in a variety of capacities. He was deputy clerk of the Supreme Court of California in 1862, secretary of the California State Board of Harbor Commissioners in the 1860s, Secretary for the University of California in 1870s (where he acted as business executive for U.C. under the presidency of Daniel Gilman). He participated in research for the United States Fish Commission in 1882, and with William Stimpson made large

collections of invertebrates from Florida for the Smithsonian Institution. He was appointed paleontologist to the United States Geological Survey by Major John Wesley Powell in 1884, and Assistant Curator of Mollusks at the Smithsonian by Spencer Baird during the same period. In his obituary of Stearns, Dall (1909:72) reports, "He (Stearns) was an enthusiastic supporter of the California Academy of Sciences in its early days, and after the earthquake of 1868, when disaster threatened the Society, he, with Professor J.D. Whitney and a few other friends, stood between it and dissolution." Stearns replaced John Trask as curator of conchology in 1865 and became director of the Academy's museum in 1868. His relationship with the Academy is covered by Leviton and Aldrich (1997). During his productive career, Stearns published numerous papers on recent mollusks as well as other invertebrate groups including octocorallian coelenterates (Fig. 4B, E, H, N) (Stearns 1873a–d, 1880) (Williams 1999:25, 28).

William G.W. Harford (1825–1911) succeeded Stearns in 1867 as curator of conchology and then served as museum director from 1876 to 1886.

Josiah Keep (1849–1911) (Fig. 1E) was elected a resident member of the Academy in 1878 and appointed Curator of Conchology in 1881. In 1885, he became Professor of Natural Sciences at Mills College. Keep was also instrumental in the development of the Pacific Grove Museum. For a biography of Josiah Keep, see Dall (1911a).

Frank Marion Anderson (1863–1945) (Fig. 1F) was appointed an honorary curator of paleontology at the Academy in 1903. His position was also at times referred to as Curator of Invertebrate Paleontology. Anderson was largely responsible for the recollection and rebuilding of the fossil and recent shells and invertebrate collections during the aftermath of the 1906 earthquake. Rodda (1987) reported, "Immediately after the fire, F.M. Anderson, then Curator of Paleontology, entered the gutted and dangerous Academy structure and recovered many fire-damaged fossils including several type specimens of ammonite species he had described. This fragile material became the nucleus of the new collections that literally rose, phoenix-like, from the ashes." Unlike most of the Academy's molluscan paleontologists, Anderson did not work on recent molluscan or other invertebrate taxa but published solely on geological topics including mollusks as fossil indicators and stratigraphy, petroleum geology, Triassic volcanoes, and Neocene deposits.

Roy Ernest Dickerson (1877–1944) (Fig. 1G) succeeded Frank Anderson as Curator of Paleontology in 1916, the same year the Academy moved into its new facility in Golden Gate Park. Dickerson was in turn succeeded by G Dallas Hanna as Curator of Paleontology in 1919. During Dickerson's limited time at the Academy, he was a prolific author. He published on fossil faunas of the Tertiary, climatic zones of the Eocene, ancient Panama canals, influence of climate on Oligocene faunas, evolution of marine molluscan faunas, and Tertiary and Quaternary history of the northern San Francisco Bay region.

Arguably, no other scientist in the Academy's history made major contributions in such a wide range of fields as G Dallas Hanna (1887–1970) (Fig. 1H) called "Doc" or "Doc Hanna" by his associates. Regarding his name, Miller (1962:5) explained,

> His [Hanna's] first name is G, just like that, no period. This causes no end of confusion among editors and bibliographers. Acquaintances of fifty years' standing have been known to call him Dallas, but most of his friends and colleagues skirt the question of which name to use by comfortably addressing him as 'Doc'.

Hanna's wide-ranging contributions and interests included wildlife and fisheries biology; opties; planetarium projector design and construction; photographic color printing; microfossils as indicators of oil rich sediments; systematics of diatoms, radiolarians, and silicoflagellates; invertebrate paleontology; and malacology. For an excellent biography of Hanna, see Miller (1962).

Leo George Hertlein (1898–1972) (Fig. 1I) also had a prolific forty-three year career as a cura-

tor of paleontology at the Academy. He was first hired as assistant curator in 1926; he retired as Curator of Paleontology in 1969. He maintained a close association with fellow curator G Dallas Hanna, as the pair co-authored many papers. Hertlein's interests were mainly in Cenozoic invertebrate paleontology (mollusks, echinoids, and brachiopods), and recent molluscan faunas of the eastern Pacific (bivalves and gastropods). He was a highly productive contributor to the fossil and recent molluscan literature, having authored over one hundred and fifty papers, including five hundred new taxa. He had a reputation for carefully produced research and curation. Addicott (1970:41) praises Hertlein's work,

> Hertlein's publications stand as models of thorough and painstaking scientific investigation, special qualities that have characterized all aspects of his scientific career. The high quality of his reports, at once obvious to anyone who has had occasion to refer to them, is the result of meticulous searching of all pertinent literature, and, wherever possible, solicitation and careful weighing of the views of associates...As a curator, his high standards are clearly reflected by the expertly and meticulously maintained invertebrate type collections in the Academy's Department of Geology as well as by the carefully arranged and labeled general collections of fossil and living invertebrates."

Biographies of Hertlein are by Emerson (1973) and Addicott (1970).

Invertebrate Zoology
1853 to 1906

The Academy's first constitution, which was adopted on 16 May 1853, specified the appointment of seven officers "and three or more curators." The three original curators elected at the subsequent meeting of 23 May 1853 were Albert Kellogg, Edwin R. Campbell, and Henry Gibbons. These appointments were curators-at-large as no research departments were identified at that time. The first departments were defined at the meeting of 6 January 1855, when William Orville Ayres was elected Curator of Zoology, W.J. Andrews as Curator of Botany, and William P. Gibbons as Curator of Geology and Mineralogy. By 1875, the Department of Zoology had been transformed and expanded into four research departments. These were Crustacea, Radiates and Ichthyology (William N. Lockington, Curator); Conchology (William G.W. Harford, Curator); Ornithology (F. Gruber, Curator), and Entomology (Henry Edwards, Curator). The two other departments were Paleontology and Mineralogy (Henry G. Hanks, Curator) and Botany (Henry N. Bolander, Curator), making a total of six research departments at the Academy by the mid-1870s. The recent invertebrate collections were dispersed among three departments — Crustacea, Radiates and Ichthyology; Conchology; and Entomology. During the 1880's, interest in invertebrates other than mollusks and insects declined. By the time the Academy moved into its elegant new facilities on Market Street in 1891, only three departments and curators were recognized — Entomology (H.H. Behr, Curator), Ornithology (L.M. Loomis, Curator), and Botany (Alice Eastwood, Curator).

Regarding invertebrate zoology during the early period of the Academy's history, Rodda (1987) writes, "During these early years there was no department of invertebrate zoology, and collections such as are now in I.Z. & G. (Invertebrate Zoology and Geology) were cared for by departments variously called Geology, Mineralogy, Paleontology, Conchology, and Zoology. Curators for these departments were honorary appointments, serving without pay."

Many important monographic studies, covering taxa other than mollusks, were conducted or published under the auspices of the Academy during the first half century of the institution's existence (see Fig. 4). Included here were Trask's 1857 paper on "zoophytes," thirteen treatments on crustaceans by William Neale Lockington (1875–1878), an account of marine annelids by Herbert

P. Johnson (1897), a treatment on gordioid nematomorphs by Thomas H. Montgomery (1898), six works on oligochaetous annelids by Dr. Gustav Eisen (1888–1900), studies on entoprocts by Alice Robertson (1900), and a large monograph on crustaceans by Samuel J. Holmes (1900).

Other notable invertebrate studies published by the Academy in the latter half of the nineteenth century included Robert E.C. Stearns (1873b–d) on nudibranch mollusks, pennatulacaean coelenterates, and shelled gastropods; William Healey Dall (1873) and James G. Cooper (1894) on shelled molluscs; William Emerson Ritter (1893) on tunicates (Fig. 4M), and William G.W. Harford (1877a, b) on crustaceans of the San Francisco Bay area.

William Neale Lockington (1840–1902)

William Lockington (Fig. 2B) became a member of the California Academy of Sciences in 1873. In 1881, the Academy Council appointed him as Curator of Ichthyology and Crustacea. He was a prolific author of many papers in invertebrate zoology, including sponges and echinoderms, but mainly crustaceans. In fact, Lockington, together with Samuel J. Holmes, can be considered as the pioneers of California crustacean taxonomy. Lockington also published on vertebrates, including sharks and rays, California market fishes, snakes, and birds. Three other papers of diverse interests, read by him at Academy meetings between 1877 and 1880, were entitled, "On the Evolution of Nerves and Nerve Tissue," "Claims of Zoology," and "Is Evolution Immoral?" He also published on subjects other than strictly scientific ones: *Day-Dreams* (1880) and *Walks Round San Francisco* (1878).

Some of his work in ichthyology sparked controversy when Theodore Gill, Professor of Zoology at George Washington University, accused Lockington, as he had on a previous occasion the Academy's William O. Ayres, of describing old species as new. The Academy's museum director, William Harford, defended the works of Lockington and Ayres at the Academy meeting of 21 November 1881. He also noted that Ayres had been so outraged by the controversy that he quit working in ichthyology altogether! (Leviton and Aldrich 1997:239).

Lockington was also a prolific collector, and added significantly to the Academy's collections of reptiles, fishes, and crustaceans, in the 1870s and 80s. He died at Worthing, Sussex, England at the age of sixty-two.

William G.W. Harford (1825–1911)

William Harford (Fig. 2A), as noted earlier, took over the curatorship in conchology from Robert Stearns (Fig. 1D) in 1867, and served as the Academy's museum director from 1876–1886. Among other contributions, Harford (1877a, b) described a new genus and three new species of crustaceans from Angel Island and Tomales Bay.

The best description of Harford's life is the brief but delightful account by Dall (1911b:8):

> We regret to record the death in Alameda, California, March 1st, of W.G.W. Harford, well known to all Pacific Coast naturalists. Mr. Harford was in his eighties and, up to a very recent date, in the possession of all his faculties. He had been the associate of the Trask, Veatch, Voy, Newcomb, Stearns, and other pioneer Pacific Coast naturalists, and for a long time kept 'bachelor's hall' in a small shack on Telegraph Hill, with the late beloved botanist Dr. A. Kellogg; practically realizing the Scotch ideal of high thinking 'on a little oatmeal.' He was long a curator at the Academy of Sciences, San Francisco, and earned a precarious livelihood by collecting seeds, plants and other objects of Natural History, and by minor appointments at the University and other scientific institutions. He was especially interested in Conchology and was appointed naturalist to the U.S. Coast Survey expedition to Alaska in 1867 under the direction of Professor George Davidson, his report is

FIGURE 2. A. William G.W. Harford. B. William Neale Lockington. C. Frank Mace MacFarland, Professor of Histology, Leland Stanford Junior University. D. Walter Kenrick Fisher. Photographs courtesy California Academy of Sciences.

printed in the *Annual Report of the U.S. Coast Survey for 1867*, Appendix 18.

He printed little and his life was devoted to helping others in their researches. Over six feet in height, of a Lincolnian gauntness, and a pioneer style of luxuriant beard and bushy eyebrows, his familiar figure will be missed by the old members of the California Academy, to whose meetings he was perennially faithful.

Gustav Augustus Eisen (1847–1940)

Regarding invertebrate zoology, two significant administrative events took place at the Academy after the founding of Stanford University's Hopkins Marine Station in the early 1890s.

Dr. Gustav Eisen (Fig. 3) was appointed Curator of Marine Invertebrates in 1899, even though the founding of the Department of Invertebrate Zoology did not take place until 1914.

Gustav Eisen was born in Stockholm, Sweden in 1847. He graduated from the University of Uppsala in 1873, then came to California to participate in a biotic survey of the state sponsored by the Swedish Academy of Sciences. "So impressed was the young explorer with the wilderness beauty and untold possibilities for scientific exploration in this state that he decided to make California his home." (Anonymous 1940:3). Eisen became a member of the Academy in 1874, a Life Member in 1883, and an Honorary Member (the Academy's highest honor) in 1938. In 1893, the Academy appointed him Curator of Archaeology, Ethnology, and Lower Animals. This unusual title reflected the eclectic interests and expertise of the appointee, a testimonial to his varied interests. Sometime prior to 1899, his title was changed to Curator of Marine Invertebrates.

A man of great Humboldtian interests, Gustav Eisen published extensively on art and art history, archeology and anthropology, agronomy and horticulture, history of science, geography and cartography, cytology, and protozoology, as well as marine invertebrate zoology. His publications dealt with specific subjects as diverse as the blood cytology of the California slender salamander, cultural history of the raisin industry, history of Academy expeditions to Baja California, biological studies of figs and caprifigs, the history of the use of glass in art, descriptions of Asian art collections, the history of the use of beads in art, developmental stages of parasitic protozoans, and the

FIGURE 3. Gustavus Augustus Eisen. A. Eisen late in life. B. Eisen (right) examining specimens. C. Eisen, from a painting by Wilford S. Conrow. D. Eisen in middle age. Photographs courtesy California Academy of Sciences.

systematics and anatomy of oligochaetous annelids. Eisen was also responsible for the introduction and propagation of the Smyrna fig and the alligator pear (avocado) to California.

> Few men in a lifetime have either the opportunity or ability to explore the many fields of knowledge in which Dr. Eisen is perfectly at home. Fewer still in this modern age of specialization have those rare qualifications which permit them to attain world renown in an amazing number of diversified fields. His task has been far more difficult, moreover, than that of the great scholars of the sixteenth and seventeenth centuries, by reason of the vast increase in human knowledge. (Anonymous 1940:3).

Along with such luminaries of late nineteenth and early twentieth century conservation as John Muir and Theodore Roosevelt, scientists such as English naturalist Alfred Russel Wallace and the Academy's Gustav Eisen voiced strong opinions regarding the destruction of the largest trees in the world, the Giant Sequoias or Big Trees (*Sequoiadendron giganteum*) and the Coast Redwood (*Sequoia sempervirens*), endemic to California's Sierra Nevada and north coast. Wallace and Muir spent a day together in the redwoods during Wallace's visit to California in 1887. His visit also included travels in the Rocky Mountains of Colorado with Academy curator-to-be Alice Eastwood. Reflecting on his day with Muir and his California travels, Wallace wrote,

> Neither the thundering waters of Niagara, nor the sublime precipices and cascades of Yosemite, nor the vast expanse of the prairies, nor the exquisite delight of the alpine flora of the Rocky Mountains — none of these seem so unique in their grandeur, so impressive in their display of the organic forces of nature, as the two magnificent 'big trees' of California. Unfortunately these alone are within the power of man totally to destroy, as they have been already partially destroyed. Let us hope that the progress of true education will so develop the love and admiration of nature that the possession of these altogether unequalled trees will be looked upon as a trust for all future generations, and that care will be taken, before it is too late, to preserve not only one or two small patches, but some more extensive tracts of forest, in which they may continue to flourish, in their fullest perfection and beauty, for thousands of years to come, as they have flourished in the past, in all probability for millions of years and over a far wider area.

Similarly, Muir wrote,

> Any fool can destroy trees…It took more than 3,000 years to make some of the trees in these western woods…Through all the wonderful, eventful centuries since Christ's time — and long before that — God has cared for these trees, saved them from drought, disease, avalanches, and a thousand straining, levelling tempests and floods; but He cannot save them from fools — only Uncle Sam can do that (Raby 2001:246).

Eisen and the Academy that he represented are in fact credited with early preservation efforts.

> Awed by the grandeur and magnificence of the Sequoias or Big Trees growing in limited numbers along the western slopes of the central and southern Sierra Nevada, and consumed by the desire to protect them for all time against the incursions of commercial lumbermen, Dr. Eisen worked for many years to bring about their conservation. In this worthy effort he asked and received the full support of the California Academy of Sciences, of which he became a member in 1874 and was a Curator from 1893 to 1900. To both the man and the institution is due much credit for the ultimate establishment of Sequoia National Park — a monument to the pioneers of conservation in the West. (Anonymous 1940:3).

Eisen, with the full support of the Academy, also worked for the preservation of Mountain Lake in San Francisco's Presidio military reservation, attempting to save it intact from potential distur-

FIGURE 4. Illustrations of invertebrates from early scientific publications by the Academy. A. *Sertularia anguina* Trask, 1857 (Coelenterata: Hydrozoa); from Trask, 1857. B. *Triopa carpenteri* Stearns, 1873, a junior synonym of *Triopha catalinae* (Cooper, 1863) (Mollusca: Nudibranchia); from Stearns, 1873b. C. *Caprella spinosa* Lockington, 1874; (Crustacea: Amphipoda); from Lockington, 1874. D. *Menipea occidentalis* Trask, 1857, a synonym of *Tricellaria occidentalis* (Trask, 1857) (Bryozoa: Cheilostomata); from Trask, 1857. E. *Verillia blakei* Stearns, 1873, a possible synonym of *Halipteris willemoesi* Köllker, 1870 (Coelenterata: Pennatulacea); from Stearns, 1873d. F. *Virgularia ornata* Fisher, 1874, possibly a species of the genus *Halipteris* (Coelenterata: Pennatulacea); from Fisher, 1874. G. *Pleurotoma circinata* Dall, 1873 (Mollusca: Gastropoda); from Dall, 1873. H. *Muricidea subangulata* Stearns, 1873 (Mollusca: Gastropoda); from Stearns, 1873. I. *Bulimulus inscendens* Binney, 1861 (Gastropoda: Pulmonata); from Cooper, 1894. Shell. J. *Sipho hallii* Dall, 1873 (Mollusca: Gastropoda); from Dall, 1873. K. *Licnophora macfarlandi* Stevens, 1901 (Protozoa: Ciliata); from Stevens, 1901. L. *Pontoscolex corethrurus* (Muller) (Annelida: Oligochaeta); from Eisen, 1900. M. *Perophora annectens* Ritter, 1893 (Chordata: Urochordata: Ascidiacea); from Ritter, 1893. N. *Conus dalli* Stearns, 1873 (Mollusca: Gastropoda); from Stearns, 1873c. O. *Gonypodaria ramosa* Robertson, 1900 (Entoprocta: Pedicellinidae); from Robertson, 1900.

bance or destruction by government road-building proposals in 1895 (Leviton and Aldrich 1997:355).

The 1906 Earthquake

Two severe earthquakes, thirty-eight years apart, threatened the existence of the Academy as an institution during its early history. The first occurred on 21 October 1868 (see Aldrich et al. 1986; Rodda and Leviton 1983), and the second, far more destructive due to the ensuing fire and larger size of the city, took place on 18 April 1906 (Hittell in Leviton and Aldrich 1997:467–476; Leviton and Aldrich 2006).

The great earthquake and fire of 1906 that devastated the city of San Francisco almost entirely destroyed the Academy's natural history collections and library. Fortunately, through the dedication of the Academy's staff and the generous support of other scientific institutions, a new Academy was built from the ruins over the succeeding decade. Institutions such as the Smithsonian, the Academy of Natural Sciences of Philadelphia, Stanford University and the University of California donated entire journal runs, and valuable books and monographs, to help in the recovery of the Academy as a valued scientific institution. Later, priceless natural history collections were transferred to the Academy from other institutions such as Stanford University and the University of California at Berkeley. In addition, during the time of the earthquake, the seed of the new collections had arrived undamaged in San Francisco Bay on board the schooner *Academy*, which provided the basis for the rebuilding of the Academy collections. The *Academy* had recently arrived from an expedition to the Galápagos Islands, where it left its geographic namesake in the name of the Bay at Puerto Ayora on Isla Santa Cruz — Academy Bay.

1906 to 1960

The citizens of the city of San Francisco soon voted for an amendment to the city charter that allowed for the building of a new museum to be situated in Golden Gate Park at the site of the 1893 Mid-Winter Fair. The newly completed buildings were occupied by staff in 1915 and first opened to the public in 1916. This original part of the post-earthquake Academy was comprised of Bird Hall, North American Hall, and the sites of the whale courtyard and the Department of Invertebrate Zoology and Geology.

The rebuilding of the collections of recent and fossil invertebrates was undertaken in the Department of Paleontology under the auspices of the Curator of Paleontology Frank Marion Anderson (Fig. 1F). Anderson initiated a program of the recollection of fossil invertebrates from the North American Pacific region. A type collection was also rebuilt, which included fossil and recent invertebrates. The largest conchological collection in western North America, the Henry Hemphill collection, was donated to the Academy in 1914. This represented the largest collection of recent invertebrates received by the Academy following the 1906 earthquake. Also in 1914, the Department of Invertebrate Zoology was formally established. In the *Report of the Director of the Museum for the Year 1915*, it is stated, "This department was re-established only a year ago, and only a small allotment was made for its use. This fund has been expended in part in starting the making of a synoptical series of the marine invertebrates of the California coast." (Miller 1960b).

Walter Kenrick Fisher (1878–1953)

Walter K. Fisher (Fig. 2D) was named Curator of the Department of Invertebrate Zoology in 1917. Fisher was an Assistant Professor of Zoology at Stanford University at the time, and a naturalist and author who published primarily on echinoderms. He occupied the position of Curator

until his death in 1953. Although he was initially paid a small salary, the position subsequently became honorary and, following his death, the Department of Invertebrate Zoology became largely inactive. "During his tenure as curator, his (Fisher's) contributions were monumental. His monographic studies of the Asteroidea, Holothuroidea, and Hydrocorallina were benchmarks in the field, and are still the definitive bases from which any taxonomic study of these groups proceeds. Much of the material used in these studies is now housed in the Academy collections." (Anonymous, ca. 1985).

Frank Mace MacFarland (1869–1951)

Close relationships between local universities and the Academy developed during the first half of the twentieth century. Several research associates as well as curatorial staff jointly held academic positions or were affiliated with nearby institutions of higher learning. This is a tradition that still flourishes today. One of these noteworthy individuals who proved to be of great importance in the development of the field of invertebrate zoology at the Academy was Frank M. MacFarland (Fig. 2C). MacFarland was also a Stanford Professor and an invertebrate zoologist. He served as the Academy's Corresponding Secretary in 1924, then as Vice President until he was elected President of the Academy in 1934. He held this post until 1946. MacFarland also served as acting Academy Director from 1934 to the beginning of Robert Miller's directorship in 1938. The Academy's invertebrate collections grew substantially during MacFarland's working relationship with the institution due largely to his interest and respected standing in the academic community. His extensive research collection of opisthobranch mollusks housed at the Academy served as a basis for an important component of the invertebrate collections. It was later augmented by Curator Terrence Gosliner (Figs. 16B, 17C) from the 1980s to present, and has become one of the largest and most significant collections of its kind in the world.

In 1966, MacFarland's important manuscript on the opisthobranch fauna of the Pacific North America was published posthumously as a hardbound *Memoir* by the Academy (Figs. 5A–C) (MacFarland 1966).

Robert Cunningham Miller (1899–1984)

By 1938, when Robert C. Miller (Figs. 6, 9C) became Director of the Academy, the recent invertebrate collections had been fragmented and were under the custody of three separate Academy departments: Paleontology, Ichthyology, and the Steinhart Aquarium. The wet collections were consolidated in 1960 in the newly reactivated Department of Invertebrate Zoology, whereas the dry collections of recent corals, mollusks, brachiopods, and echinoderms remained under the curation of the Department of Geology (known as the Department of Paleontology until it was renamed in 1953).

Miller held the position of Academy Director for twenty-five years. He was a marine invertebrate zoologist and ornithologist from the University of California. Miller encouraged the acquisition and collection of invertebrates for the Academy, as well as the publication of research regarding invertebrates. Most importantly, he also recognized the necessity of a regional center as repository for invertebrate research collections. Miller's efforts were fundamental in making the Academy the primary repository of invertebrate collections in western North America. With the reactivation of the Invertebrate Zoology Department in 1960, Miller was named as Curator and Allyn Smith, who had been in the Department of Geology, was reassigned and appointed Associate Curator of Invertebrate Zoology.

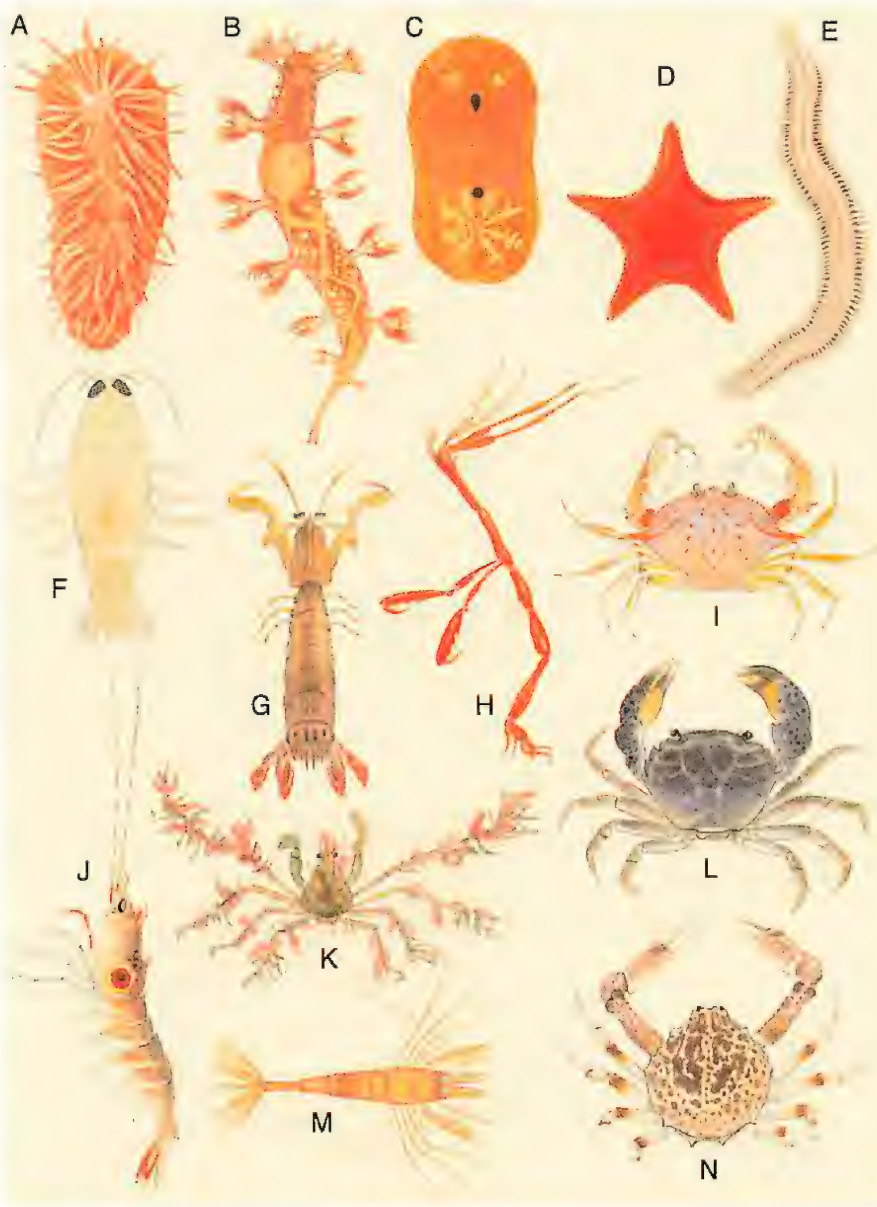

FIGURE 5. A–C. Water color illustrations of nudibranchs from MacFarland, 1966. A. *Okenia rosacea*. B. *Hancockia californica*. C. *Aldisa sanguinea*. D-N. Water color illustrations of marine invertebrates from the Templeton-Crocker expedition of 1932, to southern California and Baja California; courtesy California Academy of Sciences archives. D. Goniasterid sea star (*Mediaster aequalis*). E. Nephtyid worm (Annelida: Polychaeta: Nephtyidae). F. Flabelliferan isopod (*Aega* sp.). G. Peacock mantis shrimp (*Hemisquilla ensigera*). H. Skeleton shrimp (*Caprella* sp.). I. Calappid crab (*Platymera gaudicaudii*). J. Target shrimp (*Sicyonia penicillata*). K. Decorator crab (*Podochela* sp.). L. Xanthid crab (cf. *Panopeus* sp.). M. Caridean Shrimp (*Crangon* sp.). N. Leucosiid crab (*Randallia ornata*).

FIGURE 6. Robert Cunningham Miller, 1940s and 1950s. A. Miller as Director in his office at the Academy. B. Miller examining material from the Continental Shelf Survey on board the U.S. Navy's research vessel *Mulberry*, 1949. C. Miller on a field trip with students; to the right of Miller in a white T-shirt is Welton L. Lee (future Chairman of the Academy's Department of Invertebrate Zoology) as a teenager. D. Miller as Director of the California Academy of Sciences. Photographs courtesy California Academy of Sciences.

1960s

Reactivation of the Department of Invertebrate Zoology (1960)

Professor Donald P. Abbott of Hopkins Marine Station wrote Academy Director Robert C. Miller on 22 January 1963,

> When you wrote me some years ago of your plans for reactivating the Department of Invertebrate Zoology at the Academy, I was wholly in favor of the idea…I am very happy

> to hear that you have plans to provide the personnel and facilities, for there is most certainly a need for a central West Coast depository for collections of marine invertebrates, and the need will grow in the near future. Moreover, the Academy is the logical spot for such a depository.

In 1960, Academy Director Robert C. Miller, in his *Report to the Science Council on the Status of the Department of Invertebrate Zoology*, wrote,

> It is my recommendation that the Department of Invertebrate Zoology be reactivated, for the following reasons:
>
> The invertebrates include all of the phyla of the animal kingdom except one.
>
> There is no recognized central collection or repository of invertebrates (other than insects) on the Pacific Coast.
>
> There exists a definite need of such a collection and repository.
>
> The Academy, with a present collection of invertebrates, outside of any other department, numbering 5,000 lots and probably 50,000 specimens, has an excellent nucleus for such a repository. The collection includes a number of types of Ritter's Ascidians, Robertson's Bryozoa as restudied by C.H. O'Donohough [*sic*; O'Donoghue], and other miscellaneous types. The Director is in a position to add a large collection of marine wood-boring mollusks from various parts of the world.
>
> For reasons about to be mentioned, the Department of Invertebrate Zoology can be reactivated at a minimum of expense for the present and several years into the future.
>
> It is likely that considerable financial support can be secured from the National Science Foundation and other sources.

The mid-twentieth century was a period of blossoming interest in marine biological research along the central coast of California, made possible by the economic boom of the post World War II era. No less than four major research facilities were opened between 1948 and 1966, following the lead of Stanford University's Hopkins Marine Station, which was founded in 1892. The four marine laboratories were Pacific Marine Biological Station of the College of the Pacific at Dillon Beach (1948) , Bolinas Marine Station of the College of Marin (1963), Bodega Marine Laboratory of the University of California (1966), and Moss Landing Marine Laboratories of the California State Universities (1966). The Academy's Department of Invertebrate Zoology & Geology acquired the Hopkins Marine Station collections, including those of Ed Ricketts (Fig. 7) and Donald Abbott in the latter half of the 1970s.

A significant part of this expanded interest in Pacific coast marine biology was the reactivation of the Academy's Department of Invertebrate Zoology in 1960. In announcing the reestablishment of the Department of Invertebrate Zoology, Academy Director Robert C. Miller wrote in the Annual Report for 1960,

> During the late 1890s the Academy established a Department of Invertebrate Zoology. In recent years, however, this Department has been relatively inactive…In recognition of the importance of invertebrates (animals without backbones) which embrace the greater part of the animal kingdom, the Academy has reactivated this Department. The Board of Trustees believes that the Academy can play an important role by building up a large, well organized research and reference collection of aquatic invertebrates, emphasizing those found from Alaska to Central America. No such research collection now exists anywhere on the Pacific Coast. The Academy's collection will constitute a central repository for all research material in this broad field of science. Reactivation of this Department has been enthusiastically endorsed by neighboring colleges and universities which have indicated that a strong Department of Invertebrate Zoology at the Academy will fill an important gap

FIGURE 7. A. Two dried specimens in the Academy's invertebrate collection of the sea star *Heliaster kubiniji*, collected by Ed Ricketts and John Steinbeck in the Sea of Cortez, Mexico, 1940. B. Edward F. Ricketts with a jumbo squid (*Dosidicus gigas*) at Cannery Row, Monterey, California, circa 1940 (photo by Ralph Buchsbaum, courtesy Vicki Buchsbaum Pearse).

> now existing in the natural sciences…The Trustees named Dr. Robert C. Miller, Curator, and Allyn G. Smith, Associate Curator, of the Department. (Fig. 9C) (Miller 1960a).

Similarly, Richardson (1968:33) reported,

> It was then decided that the Department should be reactivated, a decision caused by the ever-growing interest in 'inner space'— the sea — the newest frontier in scientific research, the purpose being 'to standardize and systematize the Academy's collection of preserved Recent marine, land and freshwater invertebrates in order to make it available

> for research. For the following three years, such work as could be done in the department was done single-handedly by Allyn G. Smith, the Associate Curator. It was...decided that an appeal would be made to the National Science Foundation for a grant which would develop the department further as a centralized depository for type and other definitive biological material. To complete the job of recurating the collection and arranging it in systematic order for research, tools and personnel would be necessary...the first grant was made for a period of two years (1963–1965) and subsequently a second (1965–1967) for substantial amounts plus approximately 10% of the total from the CAS' own coffers for equipment and supplies...There were three men involved in the four-year project: Allyn G. Smith, Principal Investigator...Dr. Charles R. Stasek [Fig. 13B], who was responsible for the technical phases of the project...and Dustin Chivers, Technical Assistant, whose duties were more or less straight curatorial work.

In the same article, Richardson bluntly describes the rather austere state of the department prior to implementation of the grant, "Physically, the Department started with not much, with sort of left-over space provided, unpainted stacks, no running water, and lit by a single electric globe between the stacks. There was no proper microscope and little in the way of other curatorial equipment. The first grant took care of all this."

Allyn Goodwin Smith (1893–1976)

With respect to the development of invertebrate zoology at the Academy, Allyn G. Smith was assuredly the right person at the right time (Figs. 8A, 9). Born in Connecticut in 1893, Allyn came with his parents to Redlands, in southern California, when he was in grade school. At the age of seventeen, while on vacation in Pacific Grove, California, he met conchologist Josiah Keep (Fig. 1E) and accompanied him on a collecting trip in the Monterey Bay region. This event motivated Smith to become a shell collector. Shortly thereafter, Smith met and worked with malacologist S. Stillman Berry in Redlands. Berry most likely played an influential role in Smith's future specialty interest — the chitons (also known as polyplacophorans or amphineurans) (Howard 1969).

Smith received a B.S. degree in electrical engineering from the University of California at Berkeley in 1916. He later served as a lieutenant in the aviation section of the Signal Corps of the U.S. Army during World War I (Fig. 9B).

In the early 1920s, Smith worked as Chairman of the Technical Department for the University of California Extension at Berkeley. From 1925–1954, he was Administrative Superintendent of Personnel for Pacific Telephone and Telegraph Company. He served as Research Associate in Conchology from 1938 to 1956 in the Academy's Department of Paleontology/Geology. After retirement from his thirty-two year corporate career on 1 January 1957, he served as Research Malacologist and Assistant to the Director of the Academy from 1957 to 1960. When the Department of Invertebrate Zoology was reactivated in 1960, Smith was appointed Associate Curator and acting Chairman, and then in 1963 as Department Chairman. He served the Department well as Chairman until 1968, and then again from 1971 to the time of his retirement from the Academy in 1972. From 1968 to 1971, Victor A. Zullo (Fig. 8C) chaired both the Geology and Invertebrate Zoology Departments.

During his terms as Department Head, Smith succeeded in revitalizing the Department, overseeing rapid growth in the collections, and later stating, "The Department of Invertebrate Zoology, although the youngest of the Academy's research departments, is one of the fastest growing. Looking ahead, it should take whatever steps are needed to place itself in the position of making the maximum possible contribution toward biological research, including the training of taxonomists and systematic biologists in the invertebrate field...Working with undergraduates and gradu-

FIGURE 8. A. Allyn G. Smith, 1955. B. Welton Lee, 1976. C. Victor A. Zullo with Earl S. Herald on the television program *Science in Action*, 1960's. D. Peter U. Rodda, ca. 1971. Photographs courtesy California Academy of Sciences.

ate students in zoology, the Academy can promote such training and research and thereby develop as a vital center for such work." (Smith 1964). In 1963, a grant from the National Science Foundation was awarded to the department to standardize curation of the collections and to deal with a large backlog of material as well as rapidly accumulating new material. Charles R. Stasek (Fig. 13B) was hired as Research Biologist and Dustin D. Chivers (Figs. 9A, 10, 15A–C) was hired as Curatorial Assistant to help Smith accomplish these tasks.

In 1964, Smith participated in the Galápagos International Scientific Project, which was sponsored by the National Science Foundation, the Belvedere Scientific Fund, and the University of California, among others. While in the Galápagos Archipelago, Smith made a substantial collection of terrestrial and marine invertebrates for the Academy's Invertebrate Zoology Department.

Allyn Smith authored over one hundred scientific papers. Perhaps two of his most noteworthy publications were the Amphineura section in Moore's *Treatise on Invertebrate Paleontology*

FIGURE 9. A. Dustin D. Chivers and Allyn G. Smith, ca. 1963. B. Allyn Smith (on the right) in his U.S. Army uniform during World War I, ca. 1918, with malacologist S. Stillman Berry (at far left). C. Robert C. Miller and Allyn G. Smith, August 1960. Photographs courtesy California Academy of Sciences.

(1960), and *Land Mollusca of Baja California* (1990). Biographies of Smith are by Howard (1969), Miller (1977), and Emerson (1977).

Dustin Dale Chivers (1935–1995)

Dustin Chivers's (Figs. 9A, 10A–C, 15A–C) thirty-two year career in invertebrate zoology at the Academy as Curatorial Assistant and Senior Curatorial Assistant, spanned the time of the department's reactivation and rapid collections growth during the 1960s and 1970s. Smith (1964) stated,

FIGURE 10. Dustin D. Chivers ("Dusty"). A. Chivers with a spider crab, 1966; Photograph courtesy Department of Invertebrate Zoology and Geology, California Academy of Sciences. B. Chivers in the Academy's invertebrate collection, 1980; Photograph courtesy Department of Invertebrate Zoology and Geology, California Academy of Sciences. C. Chivers at Moss Landing Boat Harbor, California, 1992; Photograph courtesy Gary C. Williams.

> Mr. Chivers joined the Department under the NSF grant in September 1963 after working for a period with the California Department of Fish and Game in the Marine Resources Division. He is a graduate of San Francisco State College, majoring in zoology, and has served as a Supervisor of the Academy's Student Section. He is a competent SCUBA diver and collector, with a considerable and growing knowledge of invertebrate systematics and curatorial methods."

Known to his friends and associates as "Dusty," Chivers is remembered for his quick-witted

sense of humor and charismatic personality. He was an adept spokesman regarding museum public relations, as well as an important contributor to the department's marine invertebrate collections. Rodda (1995) reported,

> In addition to his museum duties Dusty added significantly to the collections. He was an important member of the Academy expeditions to the Sea of Cortez in 1964, 1965, 1978, and 1979. During his time at the Academy, the Department of Invertebrate Zoology grew enormously, becoming one of the world's premier invertebrate collections. Dusty had an astonishingly large and extensive personal knowledge of invertebrates, especially marine invertebrates from the west coast of North America, and he was broadly knowledgeable about animals and plants generally. He shared his knowledge with all who asked, freely and with pleasure. He was especially helpful to young, budding biologists who benefited greatly from his expertise in marine biology and museum techniques.

Examples of his enthusiastic outreach to young people include two of the department's present curators, Terrence Gosliner and Gary Williams, both of whom, as teenagers, owe much to Dusty's mentorship.

Franz Benno Steiner (1923–1975)

During the mid-1960s the invertebrate collections began accumulating material from the tropical Indo-Pacific. This represented a trend that continues to the present time. In fact, the majority of new material acquired by the department in the 1990s was from the Indo-Pacific. This trend has influenced the research focus of the department, which has shifted from mainly an eastern Pacific focus (1853 to the 1970s) to an Indo-Pacific one (1980s to present). From the mid-sixties to 1975, these field research efforts were due to the work of a single individual, Franz Steiner (Fig. 13C). Steiner was a field associate of the department from 1966 to the end of 1975. His extensive invertebrate collections from the tropical Indo-Pacific, particularly the Indian Ocean, which date back to the late 1950s, are considered very important components of the department's holdings. The geographical scope of his field work was impressive and included Sinagapore, Thailand, South Korea, Japan, Taiwan, Vietnam, Indonesia, Philippines, East and South China Seas, Malaysia, Pakistan, India, Sri Lanka, Saudi Arabia, Kenya, Tanzania, and South Africa. Steiner also donated Atlantic and Mediterranean material, particularly that of Morocco, Libya, Ivory Coast, Gambia, Venezuela, Brazil, and the Falkland Islands, as well as Eastern Pacific material — Peru, Chile, and El Salvador.

Steiner was born in Hamburg, Germany and as a citizen of the United States, attended Temple University in Philadelphia, Pennsylvania, worked as a merchant marine radio operator, and was an enthusiastic amateur conchologist. Much of his accumulated invertebrate collection of an estimated 15,000 lots is now housed at the Academy. He traveled and collected extensively in Europe, Africa, Asia, the West Indies, and South America, as well as the Indo-Pacific (Abbott 1973–74:453).

Invertebrate zoologist Jakob Verseveldt from Leiden's Nationaal Natuurhistorisch Museum (formerly the Rijksmuseum van Natuurlijke Historie) named a new species of coral reef soft coral (*Cladiella steineri*) for Steiner that Steiner had discovered and collected in Thailand in 1971 (Fig. 13D). Verseveldt (1982:147) states, "I name the species after Mr. Franz B. Steiner, collector of the specimens. Mr. Steiner was a radio officer for the American President Shipping Lines. He was an avid shell collector, but he also collected large series of benthic invertebrates for the Department of Inveretebrate Zoology of the California Academy of Sciences, San Francisco."

FIGURE 11. A. James T. Carlton, 1973; Photograph courtesy James T. Carlton. B. James Sutton, ca. 1976. C. Elizabeth Kools, January 1986. Photograph courtesy Department of Invertebrate Zoology & Geology, California Academy of Sciences.

1970s TO 2003

Between 1968 and 1971, Victor A. Zullo (Fig. 8C) was appointed Acting Chairman of the Department of Invertebrate Zoology as well as Chairman of the Department of Geology, succeeding Allyn Smith and G Dallas Hanna, respectively. Allyn Smith was again appointed Chairman of the Department of Invertebrate Zoology in 1971, while Peter U. Rodda (Fig. 8D) assumed the chairmanship of the Department of Geology. Allyn Smith retired a year later on 30 June 1972. Dustin Chivers was designated Acting Chairman and Assistant Curator during a transitional period of 1972–73.

James T. Carlton (Fig. 11A), who has served as an Academy Associate since 1969, is an eminent authority on introduced invertebrates of North American estuaries. Carlton served as Senior Scientific Assistant (1971–72) and Technical Assistant (1972–1973) in the Academy's Department of Invertebrate Zoology, and continues as a Research Associate. After this period of employment at the Academy in the early 1970s, Carlton obtained his doctorate at the University of California, Davis. He is currently Professor of Marine Science at Williams College, Massachusetts, and Director of the Maritime Studies Program of Williams College and Mystic Seaport. In 1975, he co-

edited Light's Manual with U.C. Berkeley zoology professor Ralph Smith (see Smith and Carlton 1975). Carlton is now editing the fourth edition of this important book, tentatively entitled, The Light and Smith Manual: Intertidal Invertebrates of the California and Oregon Coasts.

Welton L. Lee (Figs. 6C, 8B, 15E), a specialist in sponge systematics, was appointed Chairman and Curator of the Department of Invertebrate Zoology on July 1, 1973, to occupy the post vacated by Allyn Smith. Lee received his doctorate from Stanford University in 1965 and was Assistant Professor of Biology and Director of the Undergraduate Research Participation Program at Hopkins Marine Station, before coming to the Academy in 1973. As a teenager, Lee participated in the Academy's Junior Academy program (Fig. 6C).

During Lee's chairmanship of the 1970s, major managerial programs were implemented to modernize the Department and its collections. These efforts and priorities included the establishment of polices regarding future growth of the collections, major redesign of curatorial procedures, and provision for expertise in invertebrate systematics regarding the regional fauna. Concerning the latter, the first San Francisco Bay Project was initiated to develop a bibliography and consolidated reference collection of San Francisco Bay estuarine invertebrates, as well as the production of identification manuals (Light 1978; Lindberg 1981). A good deal of this effort was financed through private grants, as well National Science Foundation, Sea Grant, and Packard Foundation funding. James Sutton (Fig. 11B) was hired as project director and Research Biologist (1973–1978) for the San Francisco Bay Invertebrate Reference Collection Project.

Also during his chairmanship of the department, Lee became the Academy representative to the Association of Systematics Collections, and was elected Chairman of the ASC Council on Standards where he organized the production of a major document on the need and use of voucher specimens. In addition, Lee (pers. comm.) reports, "I was also asked by NSF to chair a joint NSF/ASC Committee which first documented the Status, Needs and Resources of 'all' U.S. Museum Invertebrate Collections. A major document was produced showing the strengths of all of these collections and a paper published with the results of our study. I was particularly proud of this accomplishment as it was produced at a time when NSF funding for Systematics was not consistent with the needs of Museum collections. I might add that Bob Van Syoc (Fig. 12D), then a Curatorial Assistant, worked with me on this venture and did an absolutely magnificent job."

Lee wrote two important NSF grants, which were awarded — first in 1979 to curate the huge backlog of material accumulated primarily as a result of Franz Steiner's field collecting around the world (particularly the Indo-Pacific), and second in 1981, to curate the ever growing dry mollusk collection that had been recently acquired.

Rodda (1987) reports,

> In 1980 the care of the dry-preserved mollusk shells was transferred from the Department of Geology to the Department of Invertebrate Zoology. Rehousing and recuration of this large collection began soon after aided by the first of a series of grants from the National Science Foundation. To support the increased mollusk collection activity Barry Roth (Fig. 12C), curatorial assistant in Geology, was transferred to Invertebrate Zoology and was appointed Senior Scientific Assistant for Malacology and Acting Assistant Curator. The same year Daphne Fautin (Fig. 12A), an authority on sea anemones, was appointed Assistant Curator, the second curator-level position in Invertebrate Zoology.

Largely due to Lee's vision, initiative, and leadership during the 1970s and 1980s, the Academy's Invertebrate Zoology Department became a modern, internationally recognized institution with collections of global scope and importance. A major accomplishment of his term was the award of a five-year National Science Foundation grant for compacterization of the invertebrate and large fossil collections between 1986 and 1989.

FIGURE 12. A. Daphne Fautin Dunn, 1987; Photograph courtesy Department of Invertebrate Zoology & Geology, California Academy of Sciences. B. Charles R. Stasek, ca. 1964/65. C. Barry Roth, 1980's; Photograph courtesy Elizabeth Kools. D. Robert J. Van Syoc, 1987; Photograph courtesy Department of Invertebrate Zoology & Geology, California Academy of Sciences.

During the early 1980s, three teams of outside consultants studied the state of research and collections at the Academy and made recommendations to the administration for improvement. In 1982, as a result of these assessments, the Departments of Geology and Invertebrate Zoology were administratively combined into one department. The new entity was at first named the Department of Invertebrate Biology and Paleontology (IBP), but was soon changed to the Department of Invertebrate Zoology and Geology (IZG).

Relevant to this, Rodda (1987:19) states,

> With the arrival in 1982 of new Executive Director Frank Talbot, several important changes were initiated. The Departments of Invertebrate Zoology and Geology were combined physically and administratively under Chairman Welton Lee. Stronger emphasis was

FIGURE 13. A. Michael T. Ghiselin, Channel Islands, California, 1991; Photograph courtesy Gary C. Williams. B. Darwin looking over the shoulder of Mike Ghiselin; cartoon by Sheridan Anderson, ca. 1971; courtesy David Lindberg, University of California, Berkeley. C. Franz B. Steiner, date not known; Photograph courtesy Department of Invertebrate Zoology and Geology, California Academy of Sciences. D. Holotype (CASIZG catalog #030117) of the soft coral *Cladiella steineri* Verseveldt, 1982; type locality Thailand; scale bar = 40 mm.

placed on research productivity, and a system of departmental collections managers was instituted to free curators to pursue research goals. In Invertebrate Zoology and Geology, Robert Van Syoc (Figs. 12D, 17C), a former Curatorial Assistant, was appointed Collections Manager to oversee all invertebrate and geological collections other than diatoms and minerals. These two units continued under the care of Honorary Curator Margaret Hanna and Mineralologist Jean DeMouthe, respectively. Also in 1982, Terrence Gosliner (Figs. 16B, 17C), a malacologist and authority on marine opisthobranch mollusks, was appointed Assistant Curator, a new permanent position; recognizing the great imporance of the large molluscan collections. Now with a staff of fourteen, Invertebrate Zoology and Geology became the largest unit in the Academy's Research Division.

Between 1982 and 1984, the new administrative attitudes toward research productivity and promotion, unfortunately resulted in some decisions regarding research personnel that proved both highly controversial and traumatic for the institution. Ultimately, this led to Welton Lee's departure from the Academy, a loss to the department and to the institution. Nonetheless, Lee continued his sponge research as a departmental Research Associate.

Regarding subsequent events, Rodda (1987) continues,

> Peter Rodda was appointed Chairman of Invertebrate Zoology and Geology succeeding Welton Lee who devoted his full-time to research on sponges. By this time, the combined Departments occupied the entire research wing of North America Hall, an area that in 1916 housed all Academy research departments, the library, and the administrative offices!...In 1985, Invertebrate Zoology and Geology received a two-year award from the National Science Foundation to computerize the type collections and to establish shared computer data bases with the Department of Paleontology, University of California, Berkeley.

Michael T. Ghiselin (Fig. 13A–B) — evolutionary biologist, Darwin scholar, former zoology professor at the University of California Berkeley, and MacArthur Foundation Fellow — joined the staff of the Academy's Invertebrate Zoology and Geology Department as Senior Research Fellow in 1983. Ghiselin received his doctorate from Stanford University in 1965 and served two post-doctoral fellowships — one with Ernst Mayr at Harvard University and another at Woods Hole Oceanographic Institution. His research concerns major aspects of evolutionary biology, chemical defense in opisthobranch gastropods, and various aspects of the history and philosophy of science. Ghiselin established the Center for the History and Philosophy of Science at the Academy in June of 1992. This recently established academic component of the Academy has resulted in important international collaborations, conferences, and publications (see: Pinna and Ghiselin 1996; Ghiselin and Pinna 1996; Ghiselin and Leviton 2000, 2004; Jablonski and Ghiselin 2005).

Elizabeth Kools (Fig. 11C) was hired as a Curatorial Assistant in Invertebrate Zoology in February of 1984. She has been largely responsible for organizing the efforts of our dedicated volunteers in curation of the Department's holdings of molluscan shells, among other curatorial duties.

In 1989, J. Patrick Kociolek was appointed the Hanna Chair of Diatoms, which was established that same year. He served as IZG department chairman from 1990–1992 and later became the Academy's Director of Research and then the institution's Executive Director (1997–2007).

Malacologist and Senior Curator Terrence M. Gosliner (Figs. 16B, 17C) served in Academy administration as the Academy's Director of Research on three occasions (1990–1993, 1997–2000, and 2005–2006), as Acting Director of Public Programs from 2000–2005, and as Academy Provost (2000–2006). The systematics of opisthobranch mollusks comprise his primary research endeavor.

Gary C. Williams (Figs. 16A, 17C) was appointed Post-Doctoral Fellow in Invertebrate Zoology in February of 1991, and then as a curator of Invertebrate Zoology (coelenterates) in 1992. Williams served as IZG department chairman from 1995–1998 and again from 2004–2008. His research specialty concerns the systematics and evolutionary biology of octocorallian coelenterates.

Building on the initial efforts of Franz Steiner in the Indian Ocean, curators Gosliner and Williams largely changed the focus of the invertebrate zoology field collecting at the Academy from the eastern Pacific to the tropical Indo-Pacific in the 1990s (Fig. 16). Their collaborative field work, involving the use of SCUBA, included Indo-Pacific islands and archipelagos such as Madagascar, the Philippines, Palau, New Guinea, Indonesia, and Palmyra Atoll.

Also in 1992, Richard Mooi (Fig. 17A) was appointed as a curator of Invertebrate Zoology (echinoderms). Mooi served as IZG department chairman from 1992–1995 and from 1998–2001. His research specialty concerns the phylogenetics and systematics of echinoderms, particularly echinoids.

Peter Rodda retired in 1997 and was succeeded in 1999 by Peter Roopnarine (Fig. 17D) as a curator of Geology. Roopnarine served as IZG department chairman from 2001 to 2004. His research interests include the evolutionary biology of Neogene marine mollusks and thermal springs gastropods, as well as the micro-evolutionary dynamics of Devonian conodonts.

Scientific Publications

Since the beginning of the publication of scientific studies at the Academy in 1854, major contributions have been made in the fields of invertebrate zoology and invertebrate paleontology. The *Proceedings of the California Academy of Natural Sciences*, volumes 1–3, were produced between 1854 and 1868. During the latter year, the name was changed to the *Proceedings of the California Academy of Sciences*, beginning with volume 4 of series 1, and this continues to the present day in series 4 of the *Proceedings* (series 4, volume 58 in 2007). Concerning this title change, Robert Stearns, the Academy's Curator of Conchology, stated, "The word Natural in the title of the Academy was dropped, upon the adoption of a new constitution in the annual meeting in January, 1868, since which time, and commencing with Volume IV, the title has been 'The California Academy of Sciences'." (Stearns 1873).

The Galápagos Islands

Academy scientists have conducted research in the Galápagos Archipelago for a century, a tradition that continues today. After the museum was destroyed in the 1906 earthquake and fire, the new collections began with specimens brought back from the 1905/06 Galápagos Expedition on board the schooner *Academy*.

Thornton (1971:18) describes this important event in the Academy's history,

> The most extensive survey of the archipelago ever undertaken was that of the expedition of the California Academy of Sciences, whose director, like Agassiz, was an opponent of the theory of evolution. Under Rollo Beck's leadership, the party sailed in the 85-foot sailing schooner *Academy* (after which Academy Bay on Indefatigable is named), and remained in the Galápagos for twelve months during 1905–6. Many young American biologists on board this vessel, such as E.W. Gifford, F.X. Williams, J.R. Slevin, and J.S. Hunter, subsequently became noteworthy scientists. The collections they made were the most comprehensive ever, and remained so until recent years. During the visit, the 1906 San Francisco earthquake occurred, destroying the Academy's museum and most of its collections; however, the material secured by the expedition was of such scope and value that the institution's position as a leading research-center was quickly restored. Since then the academy's interest in the scientific aspects of the archipelago has become traditional; its Galápagos collections are the largest in the world and its publication on Galápagos biology include many important scholarly works. The academy is generally considered the center of the research into the archipelago's natural science.

The Academy's 1932 expedition to the Galápagos Archipelago sponsored by Templeton Crocker (Fig. 14), left three fitting geographical names as a result of their explorations: Academy Bay at Puerto Ayora (Santa Cruz Island), California Cove (Fernandina Island), and Mt. Crocker (Santa Cruz Island). Germane to this, Slevin (1959:23) reports,

> In May, 1932, Captain Garland Rotch of the yacht *Zaca*, while on the Templeton Crocker Expedition of the California Academy of Sciences to the Galápagos Islands, made two sketch surveys of anchorages not yet charted. One of these was on the northeast side of Narborough Island and he called it California Cove. The other was Academy Bay,

FIGURE 14. The Academy's Templeton Crocker Expedition, 1937–1938. A. The Schooner *Zaca*. B. On board the *Zaca*. C. Templeton Crocker examining a haul taken on board the *Zaca*. Photographs courtesy California Academy of Sciences.

Indefatigable Island, locally known as Puerto Presidente Ayora, although Academy Bay is its official name.

The 1932 Expedition also pioneered a trail from Academy Bay into the highlands of Isla Santa Cruz that cut through all the elevational life zones and made access to good study sites possible (Smith 1972:7).

The 1964 Academy Expedition to the Galápagos was part of the Galápagos International Scientific Project (GISP). This major endeavor was sponsored by the Academy through the Belvedere Scientific Fund, the University of California, and the Charles Darwin Foundation, with financial and material assistance from the Republic of Ecuador, the Unites States Navy, the National Science Foundation, Shell Oil Company, and the California Maritime Commission (Smith 1972:7). Academy scientists taking part in this expedition included invertebrate zoologist Allyn Smith and

entomologist David Q. Cavagnaro. Cavagnaro Crater, approximately 1.6 km northwest of Mt. Crocker in the highlands of Santa Cruz Island, was named for the latter during this expedition.

Thirty years later, the 1994 Academy Galápagos Marine Expedition (Fig. 17C) on board the MV *Mistral*, produced many new taxa and records in invertebrate zoology and ichthyology. Taking part in this expedition, which utilized collecting by SCUBA, were Academy scientists Terrence Gosliner, John McCosker, Robert Van Syoc, Gary Williams, and underwater photographer/author Paul Humann.

The best but most often ignored example of adaptive radiation or archipelago speciation in the Galápagos Islands is not that of Darwin's finches (with a mere thirteen species) or the asteracean plant genus *Scalesia* (with twenty one taxa), but rather land snails with one hundred species, a quarter of which occur on the single island of Santa Cruz (Neil E. Fahy, pers. comm.). The single genus *Naesiotus* alone, has sixty eight described species, most of which are represented in the Academy's invertebrate collections. Academy scientists who have extensively collected Galápagos land snails include Washington H. Ochsner during the 1905/06 Expedition, and Allyn Smith during 1964 GISP Expedition. Academy publications resulting from these and earlier efforts include Dall (1917), Dall and Ochsner (1928), and Smith (1972). In addition, one hundred and two Pliocene fossil invertebrate species collected mainly by Academy scientists Joseph R. Slevin in 1927 and Leo G. Hertlein in 1931/32, are listed by Hertlein (1972).

Expeditions and Historical Collections

A summary of some of the Academy's historically significant invertebrate collections, and the expeditions that produced them, or the institutions or individuals that donated them, are as follows. Collections made in the 1890's were destroyed in the earthquake and fire of 1906.

Academy sponsored expeditions or other expeditions and surveys in which Academy scientists participated

1. Academy expeditions to Baja California by Gustav Eisen, botanists Katharine and Townshend Brandegee, and Walter Bryant, 1892 and 1893.

2. Academy expedition to the Galápagos Islands 1905–06 on board the schooner *Academy*.

3. Academy expedition to the Sea of Cortez, Mexico, in 1921, on board the 22-ton gasoline schooner *Silver Gate*.

4. Expedition to the Revillagigedo Islands in the Mexican Pacific, on board the mine sweeper U.S.S. *Ortolan*, 1925.

5. Various cruises sponsored by Templeton Crocker (Fig. 14C) on board his yacht *Zaca* (Fig. 14A–B) between 1932 and 1938; California coast and to Mexico, Baja California, the Galápagos Islands, Easter Island, and the Pacific coast of South America. The yacht was a 118-foot schooner, and its name is derived from the Samoan word for "peace". The *Zaca* was later acquired by Hollywood movie actor Errol Flynn (1909–1959) and gained the reputation as a rather notorious party boat. In 1952, Warner Brothers released a film titled *Cruise of the Zaca*, directed and narrated by Flynn. The film was a travelogue and documentary based on footage filmed in 1946.

6. Continental Shelf Survey between 1949 and 1950 (Figs. 6B, 17B), using the U.S. Navy net-tender *Mulberry*, which collected at a variety of depths up to 3660 meters. This two-year series of cruises pertained primarily to central California offshore geological research under contract with the Office of Naval Research

7. Academy expedition to the Sea of Cortez in 1953 on board the yacht *Orca*, sponsored by J.W. Sefton, Jr. of San Diego. Among the participants in this expedition were two Academy cura-

FIGURE 15. A–E. Field research, Gulf of California, 1965–1979. A. Sea of Cortez Expedition, 1965; left to right: Bruce Marquardt, Ken Lucas, Dustin Chivers. B–C. Baja Expedition on board The *Marisla*, 1979. D–E. Gulf of California Expedition, 1976. D. Baja California Shrimper. E. On the working deck, Welton Lee at left. F–G. The Academy's marine invertebrate collection, circa 1983/84. Photographs courtesy California Academy of Sciences, Department of Invertebrate Zoology and Geology.

tors, G Dallas Hanna and Joseph R. Slevin, and two Stanford graduate students who were to come to the Academy shortly thereafter, Paul H. Arnaud and Alan E. Leviton.

8. Mainland Baja California and Gulf of California island expeditions, sponsored by the Belvedere Scientific Fund, between 1958 and 1964, in which Allyn Smith, Alan Leviton, Academy entomologist Hugh Leach, Stanford botanist and Academy President, Ira Wiggins, and Academy

FIGURE 16. Field research in the Indo-Pacific, 1989–1997. A. Gary C. Williams: 1992 (inset), Photograph courtesy California Academy of Sciences; Palau, Micronesia, 1996 (center), courtesy Gary C. Williams; Maricaban Island off southern Luzon, Philippines, 1995 (right), Photograph courtesy David K. Mulliner. B. Terrence M. Gosliner: 2002 (inset), Photograph courtesy California Academy of Sciences; Madang region, Papua New Guinea, 1989 (center), Photograph courtesy Terrence M. Gosliner; Bohol Strait, Philippines, 1997 (right), Photograph courtesy David W. Behrens, CASIZG Research Associate.

Trustee Kenneth Bechtel participated. The 1964 expedition to various islands in the Gulf produced an hour length documentary film entitled, *The Sea of Cortez*. Scientists participating in this expedition included Academy Director George Lindsay, Academy invertebrate zoologist Dustin Chivers, Steinhart Aquarium Superintendent Earl S. Herald, vertebrate biologist Ray Bandar, Stanford University botanist Ira Wiggins, and Academy ornithologist/mammalogist Robert T. Orr.

9. Various expeditions by Academy Entomology Curator and natural history photographer Edward S. Ross, to Baja California, the Mexican mainland, the west coast of South America,

FIGURE 17. Field research, 1949–2004. A. Richard Mooi on board the *Polarstern*, Antarctic Peninsula, 2001; Photograph courtesy Susie Lockhart. B. Emptying the dredge on the deck of the U.S.S. *Mulberry*, Continental Shelf Survey, 1949; Photo collection of the California Academy of Sciences. C. The 1994 Academy marine expedition to the Galápagos Islands; from left to right: Terrence Gosliner, John McCosker, Gary Williams, photographer and author Paul Humann, and Robert Van Syoc; Red Beach with sea lions, Rabida Island; Photograph courtesy Terrence M. Gosliner. D. Peter Roopnarine, Gulf of Thailand, 2005; Photograph courtesy Peter Roopnarine.

Madagascar, Africa, India, Pakistan, and Australia, between 1938 and 1964. In addition to his other duties, Ross diligently collected terrestrial and freshwater mollusks, as well as some marine invertebrates for the Academy's invertebrate zoology collections.

10. The 1964 Galápagos International Scientific Project, in which the Academy was a major participant.

11. Academy Gulf of California Expeditions on board the *Marisla* in 1965 (Fig. 15A), and the *San Agustin II* in 1966.

12. Academy Gulf of California Expedition in 1976 on board a Baja California shrimper. Academy invertebrate zoologists Welton Lee and Dustin Chivers participated in this expedition (Fig. 15D–E).

13. Academy expedition to Baja California on board the *Marisla* in 1979 (Fig. 15B–C). Academy invertebrate zoologist Dustin Chivers took part in this cruise.

14. Academy expeditions between 1987 and 1998 in cooperation with the Christensen Research Institute (CRI) in Madang, Papua New Guinea, and the Coral Reef Research Foundation of Palau (CRRF) and National Cancer Institute (NCI), by Academy curators Terrence Gosliner and Gary Williams.

15. Academy expeditions to various parts of the tropical western Pacific, including the Philippines, Indonesia, the Solomon Islands, Palau, Guam, Midway Island, and Palmyra Atoll by Academy curators Terrence Gosliner and Gary Williams, between 1992 and 2001.

16. Academy Galápagos Marine Expedition in 1994 by invertebrate zoologists Terrence Gosliner, Gary Williams, and Robert Van Syoc, ichthyologist John McCosker, and underwater photographer/author Paul Humann (Fig. 17C).

Important Acquisitions from Various Agencies or Individuals

1. The Henry Hemphill conchological collection, the largest of its kind in western North America, was donated to the Academy in 1914.

2. California State Department of Fish and Game fisheries research investigations; California coast; 1940 to the 1960s; primarily deep-water marine invertebrates.

3. Invertebrates collected during World War II in the South Pacific by Dr. Wilbur M. Chapman.

4. Department of Zoology, University of California, Berkeley; extensive collection of invertebrates, some dating back to before 1900. Allyn Smith (1964:2) comments, "This collection, containing some irreplaceable type specimens, was headed for destruction for lack of space to house it and competent personnel to care for it. In 1948 the Academy agreed to provide the space and the required curatorial care for its permanent preservation in the interests of future scientific study."

5. Cephalopod mollusks collected during the expeditions sponsored by the George Vanderbilt Foundation to the Central and South Pacific between 1951 and 1954.

6. The Frank M. MacFarland (Fig. 2C) western North American opisthobranch mollusk collection acquired by the Academy in 1961. The collection was made by Professor MacFarland during his assiduous lifetime study of this group. The collection contained many undescribed taxa.

7. A collection of mollusks from the Pacific coast of Baja California made by Colonel Lee O. Miles. This collection was originally deposited with the Dillon Beach Marine Station of the University of the Pacific in 1962, but was later transferred to the Academy.

8. The Stanford University and Hopkins Marine Station collections were transferred to the Academy between 1963 and 1972. Smith (1964:4) describes the Stanford acquisition,

> A very large collection of preserved invertebrates formerly housed in the Natural History Museum at Stanford University [was] deposited with the Academy for permanent preservation and scientific study in 1963–64. This acquisition contains material from various Stanford expeditions as far back as the Hopkins-Stanford Expedition to the Galápagos Islands in 1897–98 participated in by R.E. Snodgrasss and Edmund Heller. It also contains a large series of starfish acquired by Dr. Walter K. Fisher (Fig. 2D), many invertebrates from Pt. Barrow, Alaska, and an extensive collection of crustaceans. Many type specimens are included...Addition of the Stanford Collection, estimated at ten tons of material, comes close to doubling the size of the Academy's holdings, which was already extensive. As a result, the Academy is rapidly becoming well known as a centralized depository for preserved invertebrates that can be used for scientific research by specialists and qualified students. No other institution on the Pacific Coast now has so large and so representative a collection, which is being made available for future study; and so far as known, none is

> attempting to build up and maintain one for a similar purpose. Scientists working in the field of aquatic biology must therefore rely more and more on the Academy as being about the only source of such scientific material available to them.

The October 1972 *Academy Newsletter* describes the acquisition of the Stanford University Hopkins Marine Station collections,

> A major collection of marine invertebrates of the Pacific Ocean, built up over the past half-century by leading Pacific Coast marine biologists, that had been in storage at Hopkins Marine Station in Pacific Grove, has recently been transferred to the research collections of the CAS' Department of Invertebrate Zoology...The collection, totaling more than 4,000 lots and ranging back to the mid-19th century, is judged to be of tremendous scientific and historical interest, and includes the specimens upon which many classic Pacific coast marine invertebrate studies were based. The collectors comprise a kind of 'who's who' among pioneer biologists of the coast, including David Starr Jordan, W.D. De Laubenfels, William Healey Dall, Alexander Agassiz, Libbie Hyman, S.F. Light, and many others, as well as specimens (Fig. 7A) collected by E.F. Ricketts (Fig. 7B) and John Steinbeck in the Sea of Cortez. The former is 'Doc' in Steinbeck's novel 'Cannery Row'...Included in the material are many unique specimens of marine animals rarely seen by marine biologists. And there is non-invertebrate material among which is a three-inch humback whale embryo!

An internal Academy report (Anonymous, ca. 1985) describes the Stanford and Hopkins acquisitions during the early 1970s, "During this period, the remaining collections of Stanford University were transferred to the Academy. This included a teaching and reference collection from the Hopkins Marine Station at Pacific Grove, which was soon discovered to be scientifically unique and one of the most historically important collections of west coast Invertebrata. The collection contains many specimens collected as early as the mid-19th century. Many type specimens of the ostracods described by Tage Skogsberg, and thought to be lost to science, were discovered. Well over 100 primary and secondary asteroid types of W.K. Fisher were also "rediscovered.' Many specimens bore a California Academy of Sciences label; the synoptic collection begun by the Academy in 1914 and accumulated by W.K. Fisher had finally 'come home' to the Academy."

9. Various expeditions of Franz B. Steiner (Fig. 13C), between the late 1950s and 1975, produced a wealth of marine invertebrate material for the Academy collections, mostly from the tropical Indo-Pacific, but also from the Atlantic and eastern Pacific.

Conclusion

To summarize, the California Academy of Sciences has had a strong interest in the field of invertebrate zoology since the institution's inception in 1853. This early research interest began with molluscan shell collections from the Pacific Coast of North America. A Department of Invertebrate Zoology was not established until 1914, eight years after the earthquake and fire of 1906 that wiped out the Academy's research collections. Walter K. Fisher, an eminent specialist on asteroid echinoderms, became the first Curator of the department, although Gustav A. Eisen was named Curator of Marine Invertebrates in 1899, fifteen years before a formal department was created. The original department gradually became inactive and poorly funded, but in 1960 it was formally reactivated. The department was combined with the Department of Geology (formerly Paleontology) in 1982.

Since the 1906 earthquake, the Academy's invertebrate zoology collections have grown rapidly to over half-a-million-specimen lots of recent invertebrates of worldwide scope, but with a geo-

graphical emphasis on the Pacific Basin. Taxa with the largest representation are sponges, coelenterates, mollusks, crustaceans, echinoderms, and tunicates. In addition, a large collection of fossil invertebrates — mostly mollusks — is curated and housed in the Department of Invertebrate Zoology and Geology.

With the advent and growth of the Internet since 1995, the electronic informational revolution has radically changed the way information is recorded and accessed. As with any rapid technological advance, the benefits do not come without costs. One aspect that is obviously serious and worrisome to historians is what can best be called *the deletion of history*. Prior to the mid-1990s, documentation of occurrences, events, and administrative details relevant to an institution such as the California Academy of Sciences was generally kept in the form of original letters, or copies thereof, in departmental files or institutional archives. Now, much of this type of documentation is, doubtless, deleted as "old e-mail messages" even before hard copies are made and filed. And while speaking of e-mail messages in the electronic information age, as we look to the future, we face a whole new set of problems, especially for those of us interested in knowing something of our past as a window into the future. The magnitude of the problem that this loss of voucher materials will create for future historians attempting to document research of post-mid-nineties events is likely to be enormous.

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Appendix 1

Chronology of Events Relating to the History of Invertebrate Zoology at the California Academy of Sciences

1853 (16 May) — California Academy of Sciences formally founded by adoption of the constitution, in a San Francisco office on Clay Street between Montgomery and Kearney.

1853 — Three curators-at-large without appointed specialties were added to the Academy staff: A. Kellogg, E.R. Campbell, H. Gibbons. A resolution was submitted inviting women to participate in the Academy.

1853–1906 — Contributions to the invertebrate collection were made by such notables as Alexander and Louis Agassiz, William Healey Dall, Addison Emery Verrill, Harry Beal Torrey, Samuel J. Holmes, William Emerson Ritter, Gustav Eisen, and William Neale Lockington.

1854 — In September, the Academy first publishes its *Proceedings* (Volume 1).

1867 — The Academy meets in new rooms at 622 Clay Street.

1874 — The Academy establishes its first public museum: the First Congregational Church on DuPont Street.

1875 — The number of Academy research departments had grown to six. Two of these involved marine invertebrates and were headed by: W. M. Lockington (Curator of Crustacaea, Radiates and Ichthyology) and William G.W. Harford (Curator of Conchology).

1885 — Three curators were appointed to handle their specialties, including Dr. William Orville Ayres as Curator of Zoology.

1891 — The Academy moves into larger quarters on Market Street.

1892 — Academy expedition to Baja California with Gustav Eisen.

1893 — Dr. Gustav Eisen appointed Curator of Archaeology, Ethnology, and Lower Animals.

1899 — Dr. Eisen's title was changed to Curator of Marine Invertebrates.

1905/06 — Year long Galápagos Expedition on board the schooner *Academy*.

1906 — Destruction of the Academy's research collections, library, and exhibits by the San Francisco earthquake and fire.

1906–1950 — Contributions to the invertebrate collection were made by various researchers including David Starr Jordan, Walter Kenrick Fisher, William Beebe, Sol Felty Light, and Libbie Henrietta Hyman.

1914 — Establishment of the Department of Invertebrate Zoology with the initial goal of making a synoptical series of marine invertebrates of the California coast.

1917 — Dr. Walter K. Fisher named Curator of the recently created Department of Invertebrate Zoology. He was at first paid a small salary, but in later years the position became honorary, and the Department became inactive.

1921 — Invertebrate collections made during the Academy's Baja California Expedition.

1932 and 1937–38 — Invertebrate collections made during the Academy's Templeton-Crocker Expeditions to Baja California, the Galápagos Islands, Easter Island, and the west coast of South America (see Figs. 6D-N).

1934–1939 — Dr. Frank Mace MacFarland served as acting Director of the Academy.

1938 — Dr. Robert Cunningham Miller, a marine biologist, became the Academy's Director. At that time, part of the recent invertebrate collection (mainly dried mollusks) was under the custody of the Department of Geology (known as the Department of Paleontology between 1925 and 1953).

1938–1959 — Curation of the recent invertebrate collection was by Dr. G Dallas Hanna (Curator of Geology) and Dr. Leo G. Hertlein (Associate Curator of Geology) with the assistance of three research associates: A.M. Strong, Mr. Allyn G. Smith, and Mr. Clifford C. Church. The rest of the invertebrate collection (mostly wet material preserved in alcohol or formalin) was divided and curated by Dr. W.I. Follett (Curator of Ichthyology) and Dr. Earl S. Herald, Curator of Steinhart Aquarium.

1940 — A large collection of marine invertebrates made during the expedition to Baja California by marine biologist Edward Ricketts and novelist John Steinbeck was eventually acquired by the Academy in 1963 and 1972. The events of this expedition formed the basis for their jointly authored book, *The Sea of Cortez*.

1948 — The Academy acquires the U.C. Berkeley Department of Zoology invertebrate collection.

1949 — Continental shelf survey conducted by the Academy for the Office of Naval Research under the direction of G Dallas Hanna, on board the U.S.S. *Mulberry* for dredging operations along the California coast.

1959 — The two wet collections were physically merged, resulting from new construction, and moved to a research collection room in North American Hall, previously occupied by a large herpetological collection.

1960 — Reactivation of the Department of Invertebrate Zoology by the Board of Trustees on 1 July with Dr. Robert C. Miller appointed as Curator. Mr. Allyn G. Smith, formerly a Research Malacologist in the Department of Geology, becomes the Associate Curator.

1963 — A two year NSF grant awarded to standardize and systematize the Academy's collection of preserved Recent marine, land and freshwater invertebrates in order to make it available for research. This was followed by a two-year extension from NSF.

1963 — Dr. Charles R. Stasek is appointed research biologist.

1963 — Dustin Chivers appointed technical assistant.

1963 — The invertebrate collection of the Natural History Museum of Stanford University is transferred to the Academy.

1966 and 1971 — Allyn G. Smith is appointed Chairman of the Academy's Department of Invertebrate Zoology.

1966 — Dr. Donald P. Abbot offers most of the Hopkins Marine Station invertebrate collection to the Academy.

1966 — Posthumous publication by the Academy of Frank MacFarland's Studies of Opisthobranchiate Mollusks of the Pacific Coast of North America (see Figs. 6A-C).

1968-1971 — Victor A. Zullo serves as Chairman of the Department of Invertebrate Zoology.

1972 — Allyn Smith retires as Associate Curator and Chairman of Invertebrate Zoology. Dustin Chivers is made acting Assistant Curator with James T. Carlton as half-time curatorial assistant.

1972 — Most of the Hopkins Marine Station invertebrate collection (excluding the tunicates) is transferred to the Academy.

1973 — Dr. Welton L. Lee is appointed Chairman and Curator of Invertebrate Zoology.

1980 — Dr. Daphne G. Dunn (Fautin) appointed as a Curator of Invertebrate Zoology.

1980 — Dr. Barry Roth, Acting Assistant Curator for Malacology, is transferred from the Department of Geology to the Department of Invertebrate Zoology.

1982 — The Academy's Departments of Invertebrate Zoology and Geology are combined both administratively and physically on 1 July, with Dr. Peter U. Rodda (Curator of Geology) as Chairman.

1982 — Dr. Terrence M. Gosliner appointed a Curator of Invertebrate Zoology (malacology).

1982 — Robert Van Syoc appointed collection manager for invertebrates and fossils.

1983 — Dr. Michael T. Ghiselin (evolutionary biologist and MacArthur Fellow) joins the Academy staff and is later appointed Senior Research Fellow in Invertebrate Zoology.

1984 — Jean F. DeMouthe appointed collection manager for Mineralogy.

1984 — Elizabeth Kools appointed curatorial assistant in Invertebrate Zoology.

1984 or 85 — Donald Abbot's tunicate collection transferred to the Academy from Hopkins Marine Station.

1989 — Dr. Patrick Kociolek appointed Hanna Chair of Diatoms.

1990 — Dr. Gary Williams appointed Post-Doctoral Fellow in Invertebrate Zoology, and as a Curator of Invertebrate Zoology (coelenterates) in 1992.

1992 — Dr. Rich Mooi appointed as a curator of Invertebrate Zoology (echinoderms).

1999 — Dr. Peter Roopnarine appointed as a curator of Geology.

2003 — Sesquicentennial of the California Academy of Sciences.

2004 — The Academy moves to temporary quarters in downtown San Francisco at 875 Howard Street while its buildings and museum in Golden Gate Park, that had been deemed seismically unsafe, are demolished and new buildings are constructed at the same site.

2008 — The Academy begins the move back to the the Park to occupy its newly constructed cluster of museum buildings.

Appendix 2

Department Chairs

Department of Paleontology (became the Department of Geology in 1953)

1903–1916	Frank Marion Anderson
1917–1919	Roy Ernest Dickerson
1919–1968	G Dallas Hanna
1968–1971	Victor A. Zullo
1971–1981	Peter U. Rodda

Department of Invertebrate Zoology (established 1960)

1960(63?)–1968	Allyn G. Smith
1968–1971	Victor A. Zullo
1971–1972	Allyn G. Smith
1973–1982	Welton L. Lee

Department of Invertebrate Zoology and Geology (established 1982)

1982–1987	Peter U. Rodda
1987–1990	Terrence M. Gosliner
1990–1992	J. Patrick Kociolek
1992–1995	Rich Mooi
1995–1998	Gary C. Williams
1998–2001	Rich Mooi
2001–2004	Peter Roopnarine
2004–2008	Gary C. Williams

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Short Communications

NOTES ON *FLABELLINA DANA* MILLEN AND HAMANN, 2006 FROM THE CARIBBEAN.— The description of the new aeolid *Flabellina dana* was published along with redescriptions of *F. verta* (Marcus, 1970) and *F. dushia* (Marcus and Marcus, 1967). Inadvertently, the plate of drawings depicting *Flabellina verta* (Fig. 3 in Millen and Hamann 2006) was duplicated for *Flabellina dana* in Fig. 5 (Millen and Hamann 2006). The correct illustrations for *Flabellina dana* appear here in Figure 1. In the previously published description, Figure 1D and Figure 2C, D refer to *Flabellina dana* as does all of the text including the figure caption for Figure 5.

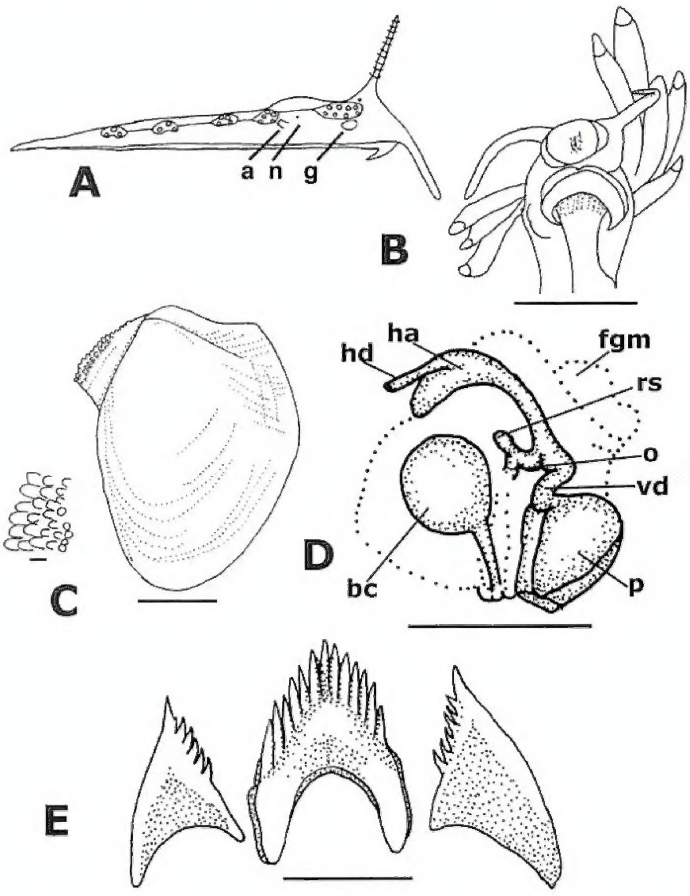

FIGURE 1. *Flabellina dana* Millen and Hamann, 2006. (St. Lucia). A. Right lateral view showing position of ceratal insertions. Key: a, anus; n, nephroproct; g, genital apertures. B. Ventral view of head and foot. Scale bar = 1 mm. C. One jaw plate, scale bar = 200 µm and masticatory margin enlarged to show denticles, scale bar = 10 µm. D. Reproductive system drawn using a camera lucida. Scale bar = 0.5 mm. Key: bc, bursa copulatrix; fgm, female gland mass; ha, hermaphroditic ampulla; hd, hermaphroditic duct; o, oviduct; p, penis; rs, receptaculum seminis; vd, vas deferens. E. One row of radular teeth. Scale bar =25 µm.

In comparing *Flabellina dana*, illustrated in Fig. 1, with *F. verta*, shown in Millen and Hamann (2006, Fig.3) the following differences become apparent: The annulate rhinophores and more forward (interhepatic) position of the anus distinguish *Flabellina dana* (Fig. 1A) from *F. verta*. As illustrated in Fig. 1B, the oral tentacles are more slender in *F. dana*. The shape of the jaw is more rounded in *F. dana* (Fig. 1C), not as triangular as in *F. verta*; and there are more rows of denticles on the masticatory margin (maximum of 8 vs. 4). In Fig. 1D, it can be seen that compared to *F. verta*, the hermaphroditic ampulla is much smaller in *F. dana*, the duct to the receptaculum seminis is much shorter but the bursa copulatrix is much larger. The penis is tapering in *F. dana* and discoid in *F. verta*. In Fig.1E, the lateral teeth of the radula are more incised at their bases and the denticles begin higher up in *F. dana*.

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MILLEN, S.V., AND J.C. HAMANN. 2006. A new nudibranch species, genus *Flabellina* (Opisthobranchia:

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